MUNICIPALITY OF COLOMBO.

REPORT

XXV

OF THE

MEDICAL OFFICER OF HEALTH,

FOR THE YEAR

1930.

Colombo:
PRINTED AT THE MUNICIPAL PRINTING OFFICE, CEYLON.

1931.

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CONTENTS.

STATISTICAL SUMMARY.

Mean temperature		80·5° F.
Rainfall		116·51 inches.
Average rainfall for the last 23 years		88·53 inches.
Area within Municipal Council's limits exclusive of lake		8,282 acres.
Population by Census of 1921		244,163
Estimated mean population for 1930		270,650
Average density per acre		32·7
Number of live births registered		9,180
Birth-rate (per 1,000 of estimated population) ...		33·9
Birth-rate (corrected for non-residents)		28·5
Maternal mortality rate (per 1,000 births) ...		29·0
Maternal mortality rate (corrected for non-residents) ...		23·7
Number of infantile deaths		1,646
Infant mortality rate (per 1,000 births)		179
Infant mortality rate (corrected for non-residents) ...		186
Percentage of infant deaths to total mortality ...		20·7
Stillbirths		675
Rate per 1,000 births live and still		68·5
Number of deaths		7,938
Crude death-rate per 1,000 population		29·3
Corrected death-rate per 1,000 population ...		23·7
Pneumonia ...	No. of deaths	925
	Death-rate	3·41 per 1,000*
Phthisis ...	No. of deaths	583
	Death-rate	2·15 per 1,000*
Enteric fever ...	No. of deaths	205
	Death-rate	0·76 per 1,000*
Plague ...	No. of deaths	38
	Death-rate	0·14 per 1,000*
Diarrhœa and enteritis	No. of deaths	846
	Death-rate	3·12 per 1,000*
Dysentery ...	No. of deaths	163
	Death-rate	0·60 per 1,000*

* The birth- and the death-rates given here are only for purposes of comparison with those of previous years.

REPORT OF THE MEDICAL OFFICER OF HEALTH FOR 1930.

I HAVE the honour to submit the Administration Report of the Public Health Department for the year 1930.

At the time of writing Part I. of this report the population figures obtained at the Census taken on February 26 were not known and the rates in this report have been calculated on the estimated population based on the previous Census population, namely, 270,654, which would appear to be lower by about 14,000 judging from the approximate figure unofficially published, namely, 284,000.

In accordance with the resolve made last year to deal fully with only one subject each year I have in this report dealt with the subject of tuberculosis which was last dealt with fairly fully by my predecessor in his report for 1917. The problem of tuberculosis is a most difficult one in every country involving as it does social and economic factors which are outside the province of a Public Health Department. In regard to this problem the line of action that promises the best results is to tackle the question of housing and overcrowding. Concentration of population within present city limits is to be deplored. The advantages of living in fresh open air surroundings should be secured for the working classes by planning and laying out Greater Colombo on Garden City lines.

The outstanding event of the year under review was the occurrence of a major flood in the month of May which had an unfavourable effect upon the health of the city (*vide* Section XV.). But for this untoward incident the morbidity and mortality rates would have been lower.

The corrected death-rate for the year was 23·7, as against 25·1 per thousand in 1929 and 22·7 the lowest rate so far recorded which was in 1927.

The birth-rate was 33·9, as against 32·3, but corrected for non-residents it was 28·5.

The infant mortality rate was 179 or corrected for non-resident mothers was 186, as against the uncorrected rate of 201 in the previous year. The infant mortality rate is beginning distinctly to respond to the work done at the centres.

The maternal mortality rate is still unsatisfactory, the crude rate being 29·0, as against 26·3, and the corrected rate being 23·7, as against 21·0 in the previous year. The effect of the Midwives' Ordinance is not noticeable yet. Puerperal septicæmia is the principal cause of the high rate. Whereas the death-rate from this cause was only 2·1 per thousand among cases conducted by Municipal midwives, the rate was 13·6 per thousand among the town cases conducted both by qualified and unqualified women. Though the Ordinance makes the practice of unqualified women a punishable offence it has been impossible so far to obtain evidence to frame a charge.

Pulmonary tuberculosis had the lowest death-rate so far recorded, namely, 2·15 per thousand. Enteric fever showed a slight set back mainly owing to the floods. There were 205 deaths, as against 184 in previous year, the death-rate being 0·76, as against 0·69.

Plague showed no increase over previous year, there being 40 cases with 38 deaths.

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Medical Officer of Health.

Town Hall,
Colombo, May 26, 1931.

Part I.—Statistics.

I.—METEOROLOGY.

Temperature.—Mean temperature in 1930 was 80·5°, as against 80·1° in 1929. Minimum temperature 79·0° in January. Maximum temperature 82·2° in April. Average mean for last 23 years 80·1°.

Rainfall.—Total for year 116·51 inches, as against 90·22 inches in 1929. Minimum monthly rainfall 0·27 inches in December. Maximum monthly rainfall 33·8 inches in October. Average for the last 23 years 88·53 inches.

Humidity.—Mean humidity was 80 per cent., as against the same in 1929. Minimum 76 per cent. in January, February, and December. Maximum 85 per cent. in October.

II.—POPULATION.

Estimated population (based on the 1921 Census) was approximately 271,000.

The 1931 Census was taken on the night of February 26, but the figuers are not yet out.

III.—BIRTHS.

9,180 live births were registered during the year representing a birth-rate of 33·9* per 1,000 population, as against 32·3 in 1929 and 31·1 the average for the previous ten years.

The birth-rate corrected for non-resident mothers in the Maternity Hospital was 28·5.

Stillbirths.—There were 675 stillbirths representing a rate of 68·5 per 1,000 births (live and still), as against 673 in 1929.

IV.—DEATHS.

*General Death-rate.**

There were 7,938 deaths, as against 8,272 in the previous year, representing crude rate of 29·3, as against 30·9 in 1929 and 31·1 the average for the previous 10 years.

The death-rate corrected by the exclusion of 1,751 deaths of non-residents in the city hospitals and the inclusion of 223 deaths of Colombo residents in extra-urban hospitals was 23·7.

A further correction for age and sex distribution gives the figure 27·6.

* The birth- and the death-rates given here are only for purposes of comparison with those of previous years.

(1) *Births and Deaths, and the Infant Mortality, for each Ward of the City of Colombo during the Year 1930.*

WARD.	BIRTHS.										DEATHS.										No. of Infant Deaths.
	TOTAL BIRTHS.			NATIONALITY.							TOTAL DEATHS.			NATIONALITY.							
	Persons.	Males.	Females.	Europeans.	Burghers.	Sinhalese.	Tamils.	Moors.	Malays.	Others.	Persons.	Males.	Females.	Europeans.	Burghers.	Sinhalese.	Tamils.	Moors.	Malays.	Others.	
Colombo City ...	9,180	4,682	4,498	90	601	5,388	1,284	1,304	320	193	7,938	3,242	3,696	40	353	4,443	1,494	1,123	239	246	1,646
Fort	2	2	—	1	—	—	—	1	—	—	14	13	1	1	1	2	4	5	—	1	—
Pettah	23	17	6	—	—	6	10	—	2	5	57	39	18	—	—	11	20	15	2	9	9
San Sebastian	262	132	129	—	8	59	22	156	8	8	222	116	106	—	1	44	44	120	5	8	64
St. Paul's	518	273	245	—	7	120	211	138	7	35	513	269	244	—	6	96	252	137	3	19	133
Kotahena	567	289	278	—	44	291	150	59	12	11	415	186	229	—	18	217	105	53	12	10	115
Mutwal	632	319	313	1	24	453	73	49	12	20	592	291	301	—	25	409	92	47	10	9	134
New Bazaar	623	319	304	—	40	226	58	248	18	33	531	251	280	—	27	160	58	237	16	33	137
Maradana North ...	568	280	288	—	42	233	68	171	34	20	457	230	227	—	25	183	85	122	27	15	133
Maradana South ...	289	149	140	—	9	159	36	51	27	7	272	153	119	2	21	145	45	42	13	4	59
Dematagoda	477	232	245	1	30	254	62	87	40	3	382	189	193	1	31	212	41	66	25	6	107
Slave Island	639	343	296	4	36	201	112	150	113	23	509	256	253	—	15	187	98	103	90	16	133
Kollupitiya	315	161	154	9	35	144	63	45	13	6	170	91	79	2	13	88	34	22	9	2	42
Cinnamon Gardens ...	81	35	46	6	11	34	19	6	4	1	55	25	30	3	3	29	12	6	2	—	15
Bambalapitiya ...	170	83	87	4	30	94	27	9	—	6	107	43	64	—	15	68	17	5	—	2	23
Timbirigasyaya ...	224	111	113	47	6	133	25	10	1	2	140	72	68	9	7	98	20	3	1	2	37
Wellawatta	353	181	172	6	50	157	69	54	10	7	179	91	88	—	22	86	42	22	5	2	47
Hospital (Town residents)											1,522	906	616	8	96	854	369	100	15	80	
Hospital (Untraced)	3,438	1,756	1,682	11	229	2,824	279	70	19	6	50	32	18	—	—	27	19	2	—	2	458
Hospital (Non-residents)											1,751	989	762	14	27	1,527	137	16	4	26	

V.—Principal Causes of Deaths.

Pneumonia caused 925 deaths or 11·7 per cent. of the total number of deaths registered in the city, and exclusive of 202 deaths of non-residents in hospitals the percentage corrected for non-residents was the same.

Diarrhœa and enteritis caused 846 deaths and dysentery 163 or a total of 1,009 deaths representing 12·7 per cent. of the total deaths, but exclusive of 198 deaths of non-residents in hospitals the percentage corrected for non-residents was 13·1.

The tuberculous diseases came next with 626 deaths.

(2) *Principal Causes of Deaths during 1930.*

Cause of Death.	No. of Deaths.	
Pneumonia and Broncho-Pneumonia ...	925	
Diarrhœa and Enteritis	846	1,009 Total Diarrhœal
*Dysentery	163	
*Pulmonary Tuberculosis	583	626 Total Tubercular Diseases
Tuberculosis of the Meninges and Central Nervous System	7	
Tuberculosis of the Intestines and Peritoneum	15	
Tuberculosis of the Vertebral Column ...	2	
Tuberculosis of the Lymphatic System ...	4	
Tuberculosis of the Joints	1	
Tuberculosis of the Bones (Vertebral Column excepted)	1	
Tuberculosis of the Genito-Urinary System ...	1	
Tuberculosis of other Organs... ...	11	
Disseminated Tuberculosis	1	
Congenital Debility (under one year) ...	527	
Influenza	418	
Infantile Convulsions (under five years of age)	226	
*Enteric Fever	205	
Malaria	149	
Continued Fever	67	
*Plague	27	

(3) *Certain Minor Causes of Death, 1930.*

Cause of Death.	No. of Deaths.
Intestinal Parasites other than Hookworm	182
Hookworm	168
Cancer	122
Paralysis (cause unspecified) ...	118
Rickets	69

Cause of Death.		No. of Deaths.
Tetanus: Under 1 year	12	73
Tetanus: 1 year and over	61	
Rabies		10
*Diphtheria		8
*Whooping Cough ...		2
Lethargic Encephalitis ...		2

(4) *Causes of Deaths registered in Colombo Town during the Year 1930.*

Causes of Death.	All Races.	Nationality: Europeans.	Burghers.	Sinhalese.	Tamils.	Moors.	Malays.	Others.
All Causes ...	7,938	40	353	4,443	1,494	1,123	239	246
I.—Epidemic, Endemic, and Infectious Diseases:—								
1.—Epidemic and Endemic Diseases ...	980	3	35	451	243	172	22	54
2.—Infectious Diseases—								
a. Tuberculous Diseases ..	626	1	35	341	121	90	16	22
b. Venereal Diseases ...	52	—	2	34	11	5	—	—
c. Other Infectious Diseases ...	148	3	2	80	43	16	1	3
II.—General Diseases not in Class I.—								
1. Cancer and Malignant Diseases ...	127	3	7	84	19	10	1	3
2. Other General Diseases not in Class I.	206	3	9	115	30	29	16	4
III.—Diseases of the Nervous System and Organs of Special Sense ...	514	3	36	282	81	82	19	11
IV.—Diseases of the Circulatory System ...	288	5	23	136	61	50	6	7
V.—Diseases of the Respiratory System ...	1,233	8	43	698	231	148	42	63
VI.—Diseases of the Digestive System ...	1,418	2	69	884	240	156	32	35
VII.—Non-venereal Diseases of the Genito-Urinary System and Annexa ...	326	2	13	183	67	42	8	11
VIII.—The Puerperal State	266	—	10	165	46	31	10	4
IX.—Diseases of the Skin and of the Cellular Tissue	73	—	3	50	11	6	1	2
X.—Diseases of the Bones and of the Organs of Locomotion	2	—	—	—	2	—	—	—
XI.—Malformations	13	—	1	6	2	3	—	1
XII.—Early Infancy	797	1	20	446	144	151	22	13
XIII.—Old Age	476	1	31	251	71	85	34	3
XIV.—External Causes—								
1.—Suicide	16	1	1	9	4	—	1	—
2.—Homicide	26	—	—	20	4	1	—	1
3.—Judicial Hanging or Execution ...	16	—	—	16	—	—	—	—
4.—Accident and other External Violence	151	1	7	85	35	13	5	5
XV.—Ill-defined Diseases	184	3	6	107	28	33	3	4

* Notifiable Infectious Diseases.

Note.—The deaths that occurred at the Infectious Diseases Hospital, which is beyond Municipal limits, are not included in the above statement.

(4) *Causes of Deaths, &c.*—contd.

Causes of Death	All Races.	Nationality. Europeans.	Burghers.	Sinhalese.	Tamils.	Moors.	Malays.	Others.
I.—EPIDEMIC, ENDEMIC, AND INFECTIOUS DISEASES.								
1.—Enteric Fever—								
a. Typhoid Fever	205	1	13	146	21	9	3	12
b. Paratyphoid Fever	—	—	—	—	—	—	—	—
2.—Typhus Fever	—	—	—	—	—	—	—	—
3.—Relapsing Fever (spirillum obermeieri) ...	—	—	—	—	—	—	—	—
4.—Malta Fever	—	—	—	—	—	—	—	—
5.—Malaria—								
a. Malarial Fever	122	—	3	59	37	13	3	7
b. Malarial Cachexia	27	—	—	17	5	1	1	3
c. Blackwater Fever	—	—	—	—	—	—	—	—
6.—Smallpox—								
a. Vaccinated	—	—	—	—	—	—	—	—
b. Unvaccinated	—	—	—	—	—	—	—	—
c. Vaccination doubtful ...	—	—	—	—	—	—	—	—
7.—Measles	—	—	—	—	—	—	—	—
8.—Scarlet Fever	—	—	—	—	—	—	—	—
9.—Whooping Cough	2	—	1	1	—	—	—	—
10.—Diphtheria	8	—	1	5	1	1	—	—
11.—Influenza—								
a. With pulmonary complications specified	82	—	—	25	20	28	1	8
b. Without pulmonary complications specified	336	—	10	112	92	92	13	17
12.—Miliary Fever	—	—	—	—	—	—	—	—
13.—Mumps	—	—	—	—	—	—	—	—
14.—Asiatic Cholera	—	—	—	—	—	—	—	—
15.—Cholera Nostras	—	—	—	—	—	—	—	—
16.—Dysentery—								
a. Amœbic	12	—	—	8	3	—	—	1
b. Bacillary	14	1	—	9	2	1	—	1
c. Other or unspecified ...	137	—	6	59	50	19	1	2
17.—Plague—								
a. Bubonic	15	—	—	5	4	5	—	1
b. Pneumonic	—	—	—	—	—	—	—	—
c. Septicæmic	12	—	—	3	6	2	—	1
d. Unspecified	—	—	—	—	—	—	—	—
18.—Yellow Fever	—	—	—	—	—	—	—	—
19.—Spirochetal Hæmorrhagic Jaundice ...	—	—	—	—	—	—	—	—
20.—Leprosy	1	—	—	1	—	—	—	—
21.—Erysipelas	4	—	—	1	2	1	—	—
22.—Acute Anterior Poliomyelitis ...	1	1	—	—	—	—	—	—
23.—Lethargic Encephalitis	2	—	1	—	—	—	—	1
24.—Meningococcus Meningitis	—	—	—	—	—	—	—	—
25.—Other Epidemic and Endemic Diseases—								
a. Chickenpox	—	—	—	—	—	—	—	—
b. German Measles	—	—	—	—	—	—	—	—
c. Kala-azar	—	—	—	—	—	—	—	—
d. Others under this title ...	—	—	—	—	—	—	—	—
26.—Glanders	—	—	—	—	—	—	—	—
27.—Anthrax	1	—	—	1	—	—	—	—
28.—Rabies (Hydrophobia)	10	—	—	10	—	—	—	—
29.—Tetanus—								
(1) Under one year	12	—	—	7	4	1	—	—
(2) One year and over	61	—	1	30	18	8	1	3
30.—Mycoses—								
a. Thrush	7	—	—	2	1	4	—	—
b. Other Mycoses	16	—	—	8	6	2	—	—
31.—Tuberculosis of the Respiratory System—								
a. Laryngeal Tuberculosis ...	—	—	—	—	—	—	—	—
b. Pulmonary Tuberculosis ...	583	1	30	319	111	86	15	21
32.—Tuberculosis of the Meninges and Central Nervous System	7	—	1	3	2	—	—	1
33.—Tuberculosis of the Intestines and Peritoneum.	15	—	2	6	4	3	—	—
34.—Tuberculosis of the Vertebral Column ...	2	—	1	—	1	—	—	—
35.—Tuberculosis of the Joints	1	—	—	1	—	—	—	—
36.—Tuberculosis of other Organs—								
a. Tuberculosis of the Skin and Subcutaneous Cellular Tissue ...	—	—	—	—	—	—	—	—
b. Tuberculosis of the Bones (Vertebral Column excepted) ...	1	—	—	—	—	1	—	—
c. Tuberculosis of the Lymphatic System (Mesenteric and Retroperitoneal Glands excepted) ...	4	—	—	3	1	—	—	—
d. Tuberculosis of the Genito-Urinary System	1	—	—	1	—	—	—	—
e. Tuberculosis of Organs other than the above	11	—	1	7	2	—	1	—
37.—Disseminated Tuberculosis—								
a. Acute	—	—	—	—	—	—	—	—
b. Chronic or unspecified ...	1	—	—	1	—	—	—	—
38.—Syphilis	48	—	2	33	10	3	—	—
38*a*.—Parangi (Framboesia Tropicum, Yaws) ...	2	—	—	—	—	2	—	—
39.—Soft Chancre	—	—	—	—	—	—	—	—
40.—Gonococcus Infection	2	—	—	1	1	—	—	—
41.—Purulent Infection, Septicæmia ...	39	3	1	21	13	1	—	—

(4) *Causes of Deaths, &c.*—contd.

Causes of Death.	All Races.	Nationality. Europeans.	Burghers.	Sinhalese.	Tamils.	Moors.	Malays.	Others.
42.—Other Infectious Diseases—								
a. Vaccinia	—	—	—	—	—	—	—	—
b. Other diseases under this title	2	—	—	1	1	—	—	—
II.—GENERAL DISEASES NOT INCLUDED IN CLASS I.								
43.—Cancer and other Malignant Tumours of the Buccal Cavity	33	—	—	19	10	4	—	—
44.—Cancer and other Malignant Tumours of the Stomach, Liver	11	—	—	5	3	—	—	3
45.—Cancer and other Malignant Tumours of the Peritoneum, Intestines, Rectum	7	—	1	4	1	1	—	—
46.—Cancer and other Malignant Tumours of the Female Genital Organs	22	—	1	17	3	—	1	—
47.—Cancer and other Malignant Tumours of the Breast	13	—	3	8	—	2	—	—
48.—Cancer and other Malignant Tumours of the Skin	—	—	—	—	—	—	—	—
49.—Cancer and other Malignant Tumours of other or unspecified Organs	36	3	1	28	2	2	—	—
50.—Tumours not returned as Malignant (Brain and Female Genital Organs excepted)	5	—	1	3	—	1	—	—
51.—Acute Rheumatic Fever	1	—	—	—	—	1	—	—
52.—Chronic Rheumatism, Osteoarthritis, Gout	19	—	—	14	3	2	—	—
53.—Scurvy	—	—	—	—	—	—	—	—
54.—Pellagra	—	—	—	—	—	—	—	—
55.—Beri-Beri	—	—	—	—	—	—	—	—
56.—Rickets	69	—	4	31	9	10	14	1
57.—Diabetes Mellitus	75	—	2	49	6	15	2	1
58.—Anæmia, Chlorosis—								
a. Pernicious Anæmia	10	1	—	4	5	—	—	—
b. Other Anæmias and Chlorosis	14	—	1	8	4	1	—	—
59.—Diseases of the Pituitary Gland	—	—	—	—	—	—	—	—
60.—Diseases of the Thyroid Gland—								
a. Exopthalmic Goitre	2	—	—	1	1	—	—	—
b. Other Diseases of the Thyroid Gland	1	—	1	—	—	—	—	—
61.—Diseases of the Parathyroid Glands	1	1	—	—	—	—	—	—
62.—Diseases of the Thymus Gland	—	—	—	—	—	—	—	—
63.—Diseases of the Adrenale (Addison's Disease)	1	—	—	—	—	—	—	1
64.—Diseases of the Spleen	—	—	—	—	—	—	—	—
65.—Leukæmia and Hodgkin's Disease—								
a. Leukæmia	4	1	—	3	—	—	—	—
b. Hodgkin's Disease	1	—	—	—	1	—	—	—
66.—Alcoholism (acute or chronic)	3	—	—	2	1	—	—	—
67.—Chronic Poisoning by mineral substances—								
a. Chronic Lead Poisoning	—	—	—	—	—	—	—	—
b. Others under this title	—	—	—	—	—	—	—	—
68.—Chronic Poisoning by organic substances	—	—	—	—	—	—	—	—
69.—Other General Diseases	5	—	1	3	—	—	—	1
III.—DISEASES OF THE NERVOUS SYSTEM AND OF THE ORGANS OF SPECIAL SENSE.								
70.—Encephalitis	6	—	2	3	1	—	—	—
71.—Meningitis—								
a. Simple Meningitis	30	2	3	21	2	2	—	—
b. Non-epidemic Cerebro-Spinal Meningitis	—	—	—	—	—	—	—	—
72.—Tabes Dorsalis (Locomotor Ataxia)	1	—	—	1	—	—	—	—
73.—Other Diseases of the Spinal Cord	5	—	1	4	—	—	—	—
74.—Cerebral Hæmorrhage, Apoplexy—								
a. Cerebral Hæmorrhage	88	—	7	37	16	23	2	3
b. Cerebral Embolism and Thrombosis.	9	—	3	4	2	—	—	—
75.—Paralysis without specified cause—								
a. Hemiphlegia	42	—	4	20	7	10	1	—
b Other forms of Paralysis	76	1	7	55	3	8	2	—
76.—General Paralysis of the Insane	1	—	—	1	—	—	—	—
77.—Other forms of Insanity	—	—	—	—	—	—	—	—
78.—Epilepsy	11	—	1	7	3	—	—	—
79.—Convulsions (non-puerperal; 5 years and over)	12	—	1	5	2	4	—	—
80.—Infantile Convulsions (under 5 years of age)	226	—	6	121	43	35	14	7
81.—Chorea	—	—	—	—	—	—	—	—
82.—Neuralgia and Neuritis	—	—	—	—	—	—	—	—
83.—Softening of the Brain	1	—	—	—	1	—	—	—
84.—Other Diseases of the Nervous System	1	—	—	1	—	—	—	—
85.—Diseases of the Eye and Annexa	—	—	—	—	—	—	—	—
86.—Diseases of the Ear and of the Mastoid Process—								
a. Diseases of the Ear	1	—	1	—	—	—	—	—
b. Diseases of the Mastoid Process	4	—	—	2	1	—	—	1
IV.—DISEASES OF THE CIRCULATORY SYSTEM.								
87.—Pericarditis	1	—	—	1	—	—	—	—
88.—Acute Endocarditis and Myocarditis	65	—	4	34	13	11	3	—
89.—Angina Pectoris	20	1	4	4	5	3	1	2

(4) *Causes of Deaths, &c.*—contd.

Causes of Death.	All Races.	Europeans.	Burghers.	Sinhalese.	Tamils.	Moors.	Malays.	Others.
		Nationality.						
90.—Other Diseases of the Heart—								
a. Valvular Disease	41	—	3	18	8	12	—	—
b. Fatty Degeneration of Heart	37	1	2	14	12	7	1	—
c. Others under this title	98	2	7	53	17	14	1	4
91.—Diseases of the Arteries—								
a. Aneurysm	3	—	—	1	2	—	—	—
b. Arteriosclerosis	7	—	3	2	1	1	—	—
c. Other Diseases of the Arteries	3	—	—	1	—	1	—	1
92.—Embolism and Thrombosis (not Cerebral)	5	1	—	3	1	—	—	—
93.—Diseases of the Veins (Varices, Hæmorrhoids, Phlebitis, &c.)	5	—	—	3	1	1	—	—
94.—Diseases of the Lymphatic System (Lymphangitis, &c.)	—	—	—	—	—	—	—	—
95.—Hæmorrhage without stated cause	3	—	—	2	1	—	—	—
96.—Other Diseases of the Circulatory System	—	—	—	—	—	—	—	—
V.—DISEASES OF THE RESPIRATORY SYSTEM.								
97.—Diseases of the Nasal Fossæ and their Annexa—								
a. Diseases of the Nose	—	—	—	—	—	—	—	—
b. Others under this title	—	—	—	—	—	—	—	—
98.—Diseases of the Larynx	9	—	3	4	1	1	—	—
99.—Bronchitis—								
a. Acute	28	—	2	11	4	6	3	2
b. Chronic	86	—	1	54	21	4	5	1
c. Unspecified (under 5 years of age)	50	—	3	22	11	11	2	1
d. Unspecified (5 years and over)	52	1	1	26	12	8	3	1
100.—Broncho-Pneumonia	431	2	21	262	59	60	19	8
101.—Pneumonia	—	—	—	—	—	—	—	—
a Lobar	229	2	6	120	49	31	—	21
b. Unspecified	265	—	3	157	54	18	10	23
102.—Pleurisy—								
a. Empyema	12	—	—	9	2	—	—	1
b. Other forms of Pleurisy	19	1	—	10	5	2	—	1
103.—Congestion and Hemorrhagic Infarct of the Lung	6	1	—	4	1	—	—	—
104.—Gangrene of the Lung	6	—	—	4	—	—	—	2
105.—Asthma	37	—	3	14	11	7	—	2
106.—Pulmonary Emphysema	—	—	—	—	—	—	—	—
107.—Other Diseases of the Respiratory System—								
a. Chronic Interstitial Pneumonia, including Occupational Diseases of the Lungs	—	—	—	—	—	—	—	—
b. Diseases of the Mediastinum	—	—	—	—	—	—	—	—
c. Others under this title	3	1	—	1	1	—	—	—
VI.—DISEASES OF THE DIGESTIVE SYSTEM.								
108.—Diseases of the Buccal Cavity and Annexa	3	—	—	3	—	—	—	—
109.—Diseases of the Pharynx and Tonsils—								
a. Tonsilitis, Adenoid Vegetations	2	—	—	2	—	—	—	—
b. Other Diseases under this title	—	—	—	—	—	—	—	—
110.—Diseases of the Œsophagus	2	—	—	1	1	—	—	—
111.—Ulcer of the Stomach or Duodenum—								
a. Ulcer of the Stomach	8	—	—	2	3	3	—	—
b. Ulcer of the Duodenum	—	—	—	—	—	—	—	—
112.—Other Diseases of the Stomach	17	—	1	9	4	3	—	—
113.—Diarrhœa and Enteritis (under 2 years of age)	302	—	26	196	27	39	10	4
114.—Diarrhœa and Enteritis (2 years and over)	544	—	21	314	116	62	16	15
115.—Anchylostomiasis	168	—	1	116	37	10	1	3
116.—Diseases due to other Intestinal Parasites—								
a. Cestodes (Hydatids of the Liver excepted)	—	—	—	—	—	—	—	—
b. Trematodes	—	—	—	—	—	—	—	—
c. Nematodes (other than Anchylostoma)	11	—	—	10	1	—	—	—
d. Coccidia	—	—	—	—	—	—	—	—
e. Other parasites specified	—	—	—	—	—	—	—	—
f. Parasites not specified	171	—	8	105	25	23	5	5
117.—Appendicitis and Typhlitis	17	—	3	9	1	1	—	3
118.—Hernia, Intestinal Obstruction—								
a. Hernia	18	—	—	10	5	3	—	—
b. Intestinal Obstruction	23	1	1	16	1	4	—	—
119.—Other Diseases of the Intestines—								
a. Psilosis (Sprue or Ceylon Sore-mouth)	—	—	—	—	—	—	—	—
b. Others under this title	3	—	—	3	—	—	—	—
120.—Acute Yellow Atrophy of the Liver	4	—	1	3	—	—	—	—
121.—Hydatid Tumour of the Liver	—	—	—	—	—	—	—	—
122.—Cirrhosis of the Liver—								
a. Specified as alcoholic	1	—	—	1	—	—	—	—
b. Not specified as alcoholic	41	—	3	28	8	1	—	1
123.—Biliary Calculi	—	—	—	—	—	—	—	—
124.—Other Diseases of the Liver	—	—	—	—	—	—	—	—
a. Abscess of Liver (Amœbiasis)	25	—	3	11	7	3	—	1
b. Others under this title	11	1	—	6	1	2	—	1

(4) *Causes of Deaths, &c.*—contd.

Causes of Death.	All Races.	Europeans.	Burghers.	Sinhalese.	Tamils.	Moors.	Malays.	Others.
		Nationality.						
125.—Diseases of the Pancreas ...	1	—	—	1	—	—	—	—
126.—Peritonitis without specified cause	45	—	1	38	3	1	—	2
127.—Other Diseases of the Digestive System	1	—	—	—	—	1	—	—
VII.—Non-venereal Diseases of the Genito-Urinary System and Annexa.								
128.—Acute Nephritis (including unspecified under 10 years of age) ...	50	1	2	24	11	8	—	4
129.—Chronic Nephritis (including unspecified 10 years and over) ...	217	1	9	122	43	28	7	7
130.—Chyluria ...	—	—	—	—	—	—	—	—
131.—Other Diseases of the Kidneys and Annexa .	19	—	2	10	5	2	—	—
132.—Calculi of the Urinary Passages	1	—	—	1	—	—	—	—
133.—Diseases of the Bladder ...	11	—	—	7	2	1	1	—
134.—Diseases of the Urethra, Urinary Abscess, &c.—								
a. Stricture of the Urethra	1	—	—	—	1	—	—	—
b. Others under this title	1	—	—	1	—	—	—	—
135.—Diseases of the Prostate ...	6	—	—	5	1	—	—	—
136.—Non-venereal Diseases of the Male Genital Organs ...	9	—	—	7	2	—	—	—
137.—Cysts and other Tumours of the Ovary not returned as malignant ...	5	—	—	2	2	1	—	—
138.—Salpingitis and Pelvic Abscess (Female) ...	1	—	—	1	—	—	—	—
139.—Tumours of the Uterus not returned as malignant	2	—	—	1	—	1	—	—
140.—Non-puerperal Uterine Hæmorrhage	—	—	—	—	—	—	—	—
141.—Other Diseases of the Female Genital Organs	3	—	—	2	—	1	—	—
142.—Non-puerperal Diseases of the Breast ...	—	—	—	—	—	—	—	—
VIII.—The Puerperal State.								
143.—Accidents of Pregnancy—								
a. Abortion ...	1	—	1	—	—	—	—	—
b. Ectopic Gestation ...	2	—	1	—	—	1	—	—
c. Other accidents of pregnancy	14	—	1	9	4	—	—	—
144.—Puerperal Hæmorrhage ...	22	—	1	12	3	3	3	—
145.—Other accidents of childbirth	18	—	1	13	4	—	—	—
146.—Puerperal Septicæmia ...	143	—	3	85	29	20	5	1
147.—Puerperal Phlegmasia, Alba Dolens, Embolism, Sudden Death ...	1	—	—	1	—	—	—	—
148.—Puerperal Albuminuria and Convulsions—								
a. Puerperal Convulsions ...	26	—	1	21	1	2	1	—
b. Puerperal Albuminuria ...	2	—	—	1	—	1	—	—
149.—Childbirth not assignable to other headings (Puerperal Insanity) ...	37	—	1	23	5	4	1	3
150.—Puerperal Diseases of the Breast ...	—	—	—	—	—	—	—	—
IX.—Diseases of the Skin and of the Cellular Tissue.								
151.—Gangrene ...	20	—	—	18	1	—	—	1
152.—Carbuncle. Boil ...	3	—	1	2	—	—	—	—
153.—Acute Abscess—								
a. Cellulitis ...	20	—	1	13	3	2	1	—
b. Acute abscess ...	15	—	1	9	3	1	—	1
154.—Other Diseases of the Skin and Annexa—								
a. Ulcer, Bedsore ...	8	—	—	5	2	1	—	—
b. Elephantiasis Arabum ...	—	—	—	—	—	—	—	—
c. Other Diseases under this title ...	7	—	—	3	2	2	—	—
X.—Diseases of the Bones and of the Organs of Locomotion.								
155.—Diseases of the Bones (Tuberculosis and Mastoid Diseases excepted) ...	2	—	—	—	2	—	—	—
156.—Diseases of the Joints (Tuberculosis and Rheumatism excepted) ...	—	—	—	—	—	—	—	—
157.—Amputations ...	—	—	—	—	—	—	—	—
158.—Other Diseases of the Organs of Locomotion	—	—	—	—	—	—	—	—
XI.—Malformations.								
159.—Congenital Malformations (Stillbirths excluded)—								
a. Congenital Hydrocephalus ...	4	—	1	—	1	1	—	1
b. Congenital Malformations of the Heart ..	1	—	—	1	—	—	—	—
c. Others under this title ...	8	—	—	5	1	2	—	—
XII.—Early Infancy.								
160.—Congenital Debility, Icterus, and Sclerema	527	—	13	239	108	135	21	11
161.—Premature Birth : Injury at Birth—								
a. Premature Birth ...	254	—	6	195	35	15	1	2
b. Injury at Birth ...	—	—	—	—	—	—	—	—

(4) *Causes of Deaths, &c.*—contd.

Causes of Death.	All Races.	Nationality. Europeans.	Burghers.	Sinhalese.	Tamils.	Moors.	Malays.	Others.
162.—Other Diseases peculiar to Early Infancy ...	16	1	1	12	1	1	—	—
163.—Lack of Care	—	—	—	—	—	—	—	—
XIII.—OLD AGE.								
164.—Senility	476	1	31	251	71	85	34	3
XIV.—EXTERNAL CAUSES.								
165.—Suicide by Solid or Liquid Poisons (Corrosive substances excepted)	4	—	—	2	1	—	1	—
166.—Suicide by Corrosive substances ...	1	—	1	—	—	—	—	—
167.—Suicide by Poisonous Gas	—	—	—	—	—	—	—	—
168.—Suicide by Hanging or Strangulation ...	2	—	—	1	1	—	—	—
169.—Suicide by Drowning	2	—	—	1	1	—	—	—
170.—Suicide by Firearms	1	—	—	1	—	—	—	—
171.—Suicide by Cutting or Piercing Instruments	4	1	—	3	—	—	—	—
172.—Suicide by Jumping from high places ...	—	—	—	—	—	—	—	—
173.—Suicide by Crushing	—	—	—	—	—	—	—	—
174.—Suicide by other means	2	—	—	1	1	—	—	—
175.—Poisoning by Food	1	—	—	1	—	—	—	—
176.—Poisoning by Venomous Bites and Stings—								
a. Snake-bite	—	—	—	—	—	—	—	—
b. Insect Stings	—	—	—	—	—	—	—	—
c. Other Venomous Poisonings ...	—	—	—	—	—	—	—	—
177.—Other Acute Accidental Poisonings ...	5	—	—	4	1	—	—	—
178.—Conflagration	—	—	—	—	—	—	—	—
179.—Accidental Burns (Conflagration excepted) .	21	—	1	11	5	3	1	—
180.—Accidental Mechanical Suffocation ...	4	—	—	1	3	—	—	—
181.—Accidental Absorpton of Irrespirable, Irritating, or Poisonous Gas ...	—	—	—	—	—	—	—	—
182.—Accidental Drowning	22	—	1	10	6	4	—	1
183.—Accidental Traumatism by Firearms (Wounds of War excepted) ...	—	—	—	—	—	—	—	—
184.—Accidental Traumatism by Cutting or Piercing Instruments	—	—	—	—	—	—	—	—
185.—Accidental Traumatism by Falls—								
a. From Trees	4	—	—	3	1	—	—	—
b. From Heights other than trees ...	2	1	—	1	—	—	—	—
c. Traumatism by other Accidental Falls	14	—	—	5	5	2	—	2
186.—Accidental Traumatism in Mines and Quarries	1	—	—	—	1	—	—	—
187.—Accidental Traumatism by Machines ...	1	—	—	—	—	—	—	1
188.—Accidental Traumatism by other Crushing—								
a. Cart or Carriage	3	—	—	3	—	—	—	—
b. Landslides	—	—	—	—	—	—	—	—
c. Motor Vehicles	35	—	4	20	6	1	3	1
d. Railways	7	—	—	3	2	1	1	—
e. Others under this title ...	13	—	—	10	2	1	—	—
189.—Injuries by Animals (Poisoning by Venomous Bites and Stings excepted) ...	2	—	—	2	—	—	—	—
190.—Wounds of War	—	—	—	—	—	—	—	—
191.—Execution of Civilians by Belligerent Armies	—	—	—	—	—	—	—	—
192.—Starvation (Hunger or Thirst) ...	6	—	—	5	1	—	—	—
193.—Excessive Cold	—	—	—	—	—	—	—	—
194.—Excessive Heat	—	—	—	—	—	—	—	—
195.—Lightning	—	—	—	—	—	—	—	—
196.—Electricity (Lightning excepted) ...	—	—	—	—	—	—	—	—
197.—Homicide by Firearms	3	—	—	3	—	—	—	—
198.—Homicide by Cutting or Piercing Instruments	14	—	—	11	2	1	—	—
199.—Homicide by other means	7	—	—	5	2	—	—	—
200.—Infanticide (murder of infant less than 1 year of age) ...	2	—	—	1	—	—	—	—
201.—Fractures (cause not specified) ...	9	—	1	6	1	1	—	—
202.—Other External Violence—								
a. Judicial Execution	16	—	—	16	—	—	—	—
b. Others under this title ...	1	—	—	—	1	—	—	—
203.—Violent deaths of unknown causation ...	—	—	—	—	—	—	—	—
XV.—ILL-DEFINED DISEASES.								
204.—Sudden death	—	—	—	—	—	—	—	—
205.—Cause of death not specified or ill-defined—								
a. Dropsy	4	—	—	3	—	1	—	—
b. Heart Failure	17	2	3	5	5	1	—	1
c. Pyrexia	68	1	—	37	15	11	3	1
d. Other Ill-defined diseases ...	94	—	3	61	8	20	—	2
e. Not specified or unknown ...	1	—	—	1	—	—	—	—

VI.—Infant Mortality.

There were 1,646 deaths, as against 1,738 in the previous year, representing an infant mortality rate of 179, the lowest rate so far recorded. When corrected for non-residents the rate is 186, but even this shows an improvement over previous years (*vide* Statement 5).

The principal causes of deaths were atrophy and debility, premature birth, and diarrhœal diseases (*vide* Statement 6).

The mortality rates for all these diseases were however less than the corresponding figures for the previous year.

But for the floods in May the infant mortality rate would have been still lower (*vide* Diagram 1).

(5) *Births and Infantile Deaths and the Infant Mortality Rates for Colombo Town, 1921 to 1930.*

Year.	No. of Births.	No. of Infant Deaths.	Infant Mortality Rate per 1,000 Births.	Infant Mortality Rate corrected for Non-residents.
1921	8,724	2,098	240	—
1922	6,881	1,702	247	—
1923	7,107	1,929	271	—
1924	6,887	1,643	239	—
1925	7,663	1,689	220	—
1926	8,114	1,658	204	—
1927	8,491	1,584	187	196
1928	9,486	1,714	181	189
1929	8,659	1,738	201	208
1930	9,181	1,646	179	186

(6) *Principal Causes of Infant Mortality in 1930.*

Expressed as a percentage of Total Infant Deaths.

Cause of Death	No. of Deaths	Percentage.
Atrophy and Debility	527	32·0
Permature Birth	254	15·4
Diarrhœal Diseases	218	13·2
Pneumonia	171	10·4
Convulsions	168	10·2

(7) *Infant Mortality by Race, 1930—Number of Infant Deaths and Rate per 1,000 Births.*

Race.	No. of Infant Deaths, 1930.	Rate per 1,000 Births, 1930.	Rate per 1,000 Births, Previous Year.	Increase or Decrease of 1930 Rate when compared with 1929 Rate.
All Races	1,646	179	201	— 22
Europeans	2	22	24	— 2
Burghers	63	105	136	— 31
Sinhalese	902	167	190	— 23
Tamils	284	221	253	— 32
Moors	288	221	241	— 20
Malays	71	222	182	+ 40
Others	36	187	222	— 35

(8) *Infant Mortality, 1930, by Wards—Rate per 1,000 Births.*

Ward.	Average, 1925 to 1929.	1929.	1930.	Increase or Decrease of 1930 Rate when compared with that of 1929.
Colombo Town	199	201	179	— 22
Fort	—	—	—	—
Pettah	204	45	391	+346
San Sebastian	248	222	245	+ 23
St. Paul's	280	278	257	— 21
Kotahena	243	230	203	— 27
Mutwal	242	266	212	— 54
New Bazaar	263	265	220	— 45
Maradana North	252	286	234	— 52
Maradana South	231	200	204	+ 4
Dematagoda	229	259	224	— 35
Slave Island	215	194	208	+ 14
Kollupitiya	169	122	133	+ 11
Cinnamon Gardens	176	145	185	+ 40
Bambalapitiya	143	209	135	— 74
Timbirigasyaya	191	223	165	— 58
Wellawatta	153	137	133	— 4
Hospitals	136	146	133	— 13

(9) *Infant Mortality by Race, during the Year 1930—Rate per 1,000 Births.*

Cause	All Races.	Europeans.	Burghers	Sinhalese.	Tamils.	Moors.	Malays.	Others.
All Causes	179	22	105	167	221	221	222	187
Premature Birth	28	—	10	36	27	12	3	11
Atrophy and Debility	57	—	22	44	85	103	66	62
Bronchitis	5	—	3	4	8	7	16	5
Pneumonia	19	—	14	21	19	8	31	21
Diarrhœal Diseases	24	—	30	26	16	23	25	16
Convulsions	18	—	7	14	26	23	31	31
Tetanus	1	—	—	2	3	0·8	—	—
All other causes	27	22	19	20	37	44	50	41

(10) *Causes of Infant Mortality, 1921 to 1930—Number of Deaths.*

Cause of Infant Deaths.	1921	1922	1923	1924	1925	Average, 1921–1925	1926	1927	1928	1929	1930
Developmental Diseases ...	706	603	685	617	602	643	609	676	820	765	800
Pneumonia and Bronchitis ...	311	251	263	213	241	256	228	254	257	268	218
Digestive Diseases	279	225	262	235	220	244	226	202	194	242	238
Convulsions	602	411	480	409	426	466	420	256	208	184	168
Tetanus Neonatorum... ...	16	17	7	22	13	15	18	9	12	3	12
Tuberculosis	19	9	10	4	2	9	—	1	—	—	1
Syphilis	33	44	59	36	37	42	34	29	31	23	28

(11) *Causes of Infant Mortality, 1921 to 1930—Rate per 1,000 Births.*

Cause of Infant Deaths.	1921	1922	1923	1924	1925	Average, 1921–1925	1926	1927	1928	1929	1930
Developmental Diseases ...	81	88	96	90	78	87	75	80	86	88	87
Pneumonia and Bronchitis ...	36	36	37	31	31	34	28	30	27	31	24
Digestive Diseases	32	33	37	34	29	33	28	24	20	28	26
Convulsions	69	60	68	59	56	62	52	30	22	21	18
Tetanus Neonatorum ...	2	2	1	3	2	2	2·2	1·1	1	0·3	1·3
Tuberculosis	2	1	1	0·6	0·3	1	—	0·1	—	—	0·1
Syphilis	4	6	8	5	5	6	4	3·2	3·3	3	3

(12) *Infant Mortality—Deaths at different Age Periods and from Several Causes.*—1930.

Cause of Death.	Age.													Race.							
	Age in Weeks.					Age in Months.															
	1	2	3	4	Total.	2	3	4	5	6	7–9	10–12	Total.	Europeans.	Burghers.	Sinhalese.	Tamils.	Moors.	Malays.	Others.	All Races.
I.—Developmental Diseases:—																					
1. Premature birth ...	217	14	12	6	249	2	2	—	—	—	—	1	5	—	6	195	35	15	1	2	254
2. Atelectasis ...	1	—	—	—	1	—	—	—	—	—	—	—	—	1	—	—	—	—	—	—	1
3. Atrophy and Debility	223	44	29	50	346	63	31	21	13	14	25	14	181	—	13	238	109	134	21	12	527
4. Rickets ...	—	1	—	—	1	2	2	3	—	1	8	1	17	—	—	6	3	1	8	—	18
II.—Diseases of Respiratory System :—																					
1. Laryngitis ...	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
2. Croup ...	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
3. Bronchitis ...	1	2	2	—	5	7	6	6	6	3	11	3	42	—	3	18	11	9	5	1	47
4. Pneumonia ...	4	1	—	3	8	8	26	14	14	16	50	35	163	—	8	114	24	11	10	4	171
5. Others ...	2	—	—	—	2	—	—	—	—	—	—	1	1	—	—	1	1	—	—	1	3
III.—Diseases of Digestive System :—																					
1. Diarrhœa and Enteritis	1	2	5	9	17	30	31	20	16	16	52	32	197	—	17	137	21	28	8	3	214
2. Dysentery ...	—	—	—	—	—	—	—	—	—	—	4	—	4	—	1	1	—	2	—	—	4
3. Others ...	2	—	1	2	5	2	2	1	3	—	4	3	15	1	—	11	3	4	1	—	20
IV.—Diseases of Nervous System :—																					
1. Convulsions ...	29	8	8	9	54	21	19	12	11	9	30	12	114	—	4	85	33	30	10	6	168
2. Laryngismus stridulus	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
3. Tetanus ...	4	7	1	—	12	—	—	—	—	—	—	—	—	—	—	7	4	1	—	—	12
4 Others ...	—	—	—	—	—	—	—	—	—	—	—	1	1	—	—	—	1	—	—	—	1
V.—Tuberculous Diseases:—																					
1. Tabes messenterica ...	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
2. Tubercular meningitis	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
3. Others ...	—	—	—	—	—	—	—	—	—	—	1	—	1	—	—	1	—	—	—	—	1
VI.—Accidents:—																					
1. Injury ...	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
2. Umbilical hæmorrhage	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
3. Suffocation ...	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
4 Other violence ...	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
VII.—Infectious Diseases:—																					
1. Smallpox ...	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
2. Chickenpox ...	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
3. Measles ...	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
4. Whooping cough ...	—	—	—	—	—	1	—	—	—	—	—	—	1	—	—	1	—	—	—	—	1
5. Mumps ...	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
6. Diphtheria ...	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
7. Influenza ...	3	2	1	4	10	11	5	13	19	10	20	19	97	—	4	28	27	39	6	3	107
8. Enteric fever ...	—	—	—	—	—	—	1	—	—	—	—	—	1	—	—	1	—	—	—	—	1
VIII.—Syphilis ...	—	—	—	3	3	6	6	2	3	1	5	2	25	—	1	22	3	2	—	—	28
IX.—All other causes ...	20	6	6	5	37	4	2	5	5	2	9	4	31	—	6	36	9	12	1	4	68
Total ...	507	87	65	91	750	157	133	97	90	72	219	128	896	2	63	902	284	288	71	36	1646
Percentage on Total Infant Deaths ..	30·7	5·3	3·9	5 5	45·6	9·5	8·1	5·9	5·5	4·4	13·3	7·9	54·4	·1	3·8	54·8	17·3	17·5	4·3	1·9	—

VII.—Infectious Diseases (General.)

Enteric fever showed an increase of 72 cases, continued fever of 5 cases, and phthisis of 16 cases over previous year. Plague showed no increase. Measles and chickenpox showed a marked decrease.

(13) *Notifiable Infectious Diseases, 1930.*

Disease.	(a) TOWN CASES. January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	(b) Total Town Cases.	(c) Port Cases	(d) Outside Cases.	(e) Grand Total, 1930.	(f) Total Town Cases Previous year.
Plague ...	4	3	3	3	4	—	3	4	1	2	5	8	40	—	—	40	40
Cholera ...	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1
Smallpox ...	1	1	—	—	—	—	—	—	—	—	—	—	2	3	1	6	2
Chickenpox ...	111	119	110	107	61	51	77	69	76	55	36	25	897	5	90	992	1,288
Measles ...	6	7	8	50	40	—	9	3	—	7	2	2	134	—	4	138	831
Diphtheria ...	2	1	3	1	2	1	4	1	3	2	—	3	23	1	10	34	33
Acute Diarrhœa ...	1	—	—	—	—	—	—	—	—	—	—	—	1	—	—	1	—
Enteric Fever ...	30	31	31	24	37	38	48	46	30	19	18	21	373	6	467	846	301
Continued Fever ...	13	10	10	4	8	22	19	20	9	8	3	11	137	—	50	187	132
Phthisis ...	79	49	77	66	91	83	78	88	73	99	69	66	918	4	397	1,319	902
Scarlet Fever ...	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Typhus Fever ...	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Dysentery ...	43	22	10	10	17	71	118	33	38	19	18	12	411	7	124	542	435
Whooping Cough ...	9	2	—	10	—	1	6	7	1	1	—	—	37	—	5	42	59

(14) *Infectious Diseases Recorded (Town Cases), 1921 to 1930.*

Diseases.	1921	1922	1923	1924	1925	1926	1927	1928	1929	1930
Plague ...	184	136	230	148	64	13	83	40	40	40
Cholera ...	—	—	—	1	3	—	—	1	1	—
Smallpox ...	12	34	3	4	1	10	2	10	2	2
Chickenpox ...	711	699	1,235	790	1,703	1,045	887	1,520	1,288	897
Measles ...	190	226	761	650	627	518	102	612	831	132
Diphtheria ...	20	16	19	11	14	17	18	20	33	23
Enteric Fever ...	398	341	535	415	473	249	206	230	301	373
Continued Fever ...	187	115	105	231	243	168	136	127	132	137
Phthisis ...	1,367	1,181	1,343	1,146	1,146	977	810	910	902	918
Dysentery ...	Not notifiable during these years								435	411
Whooping Cough ...	Not notifiable during these years								59	37

VIII.—Plague.

(a) *Human Plague.*

Number of Cases.—The total number of cases during 1930 was 40, as against the same number in 1928 and 1929. 38 of this number proved fatal, representing a case mortality of 95 per cent.

Type of Case.—14 were septicæmic with a case mortality of 100 per cent. 25 were bubonic with 23 deaths, case mortality 92 per cent. 1 case was cutaneous, ended fatally.

Monthly Incidence.—The largest number of cases occurred during the last quarter of the year. 8 cases occurred in December alone.

Sex Incidence.—37 males; 3 females.

Race Incidence.—Tamils: 16 cases, all fatal. Moors: 12 cases, 11 fatal. Sinhalese: 11 cases, 10 fatal. Malayalee: 1 case, fatal.

Distribution by Wards.—(See Statement 15).

(b) *Rat Plague.—Number Trapped and Destroyed.*

In city	100,444
In Chalmers Granaries ...	1,713
In Manning Markets ...	600
Killed by Fumigators ...	1,537
Found dead	29
Found mummified ...	8
Total number accounted for ...	104,331

Number of rats examined at Laboratory 21,542

Number found infected ... 13 or 0·06 per cent.

(15) *Distribution of Infected Rats.*

Pettah	5*	Timbirigasyaya	1
St. Paul's	5	Wellawatta	1
Bambalapitiya ...	1		
	11	Total ...	13

* Includes 3 from Chalmers Granaries

Preventive Measures.—The usual preventive measures were carried out special attention being paid to the endemic areas.

Statement 18 shows the work done by the Anti-Plague Squad.

(16) *Human Plague, 1930.*

Distribution by Wards.

Ward.	No. of Cases.	No. of Deaths.	Ward.	No. of Cases.	No. of Deaths.
Fort ...	—	—	Slave Island ...	—	—
Pettah ...	8	7	Kollupitiya ...	1	1
San Sebastian ...	3	3	Cinnamon Gardens ...	—	—
St. Paul's ...	15	15	Bambalapitiya ...	2	2
Kotahena ...	—	—	Timbirigasyaya ...	—	—
Mutwal ...	1	1	Wellawatta ...	3	2
New Bazaar ...	4	4	Untraced ...	1	1
Maradana North ...	1	1			
Maradana South ...	—	—	Total ...	40	38
Dematagoda ...	1	1			

(17) *Human Plague in Colombo during the Year 1930—Distribution by Race, Sex, and Age.*

Race.	Sex.	0 to 5 Years.	5 to 10 Years.	10 to 15 Years.	15 to 20 Years.	20 to 25 Years.	25 to 30 Years.	30 to 35 Years.	35 to 40 Years.	40 to 50 Years	50 to 60 Years.	60 Years and Over.	Total.	Total of each Race.	No. of Deaths (inclusive of Deaths of Colombo cases at I.D.H.)	Case Mortality Per Cent.
All Races ...	Males ...	—	2	9	7	5	8	1	—	5	—	—	37	40	38	95
	Females ...	—	—	—	1	1	—	1	—	—	—	—	3			
Europeans ...	Males ...	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	Females ...	—	—	—	—	—	—	—	—	—	—	—	—			
Burghers ...	Males ...	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	Females ...	—	—	—	—	—	—	—	—	—	—	—	—			
Sinhalese ...	Males ...	—	1	4	2	—	—	—	—	1	—	—	8	11	10	90·9
	Females ...	—	—	—	1	1	—	1	—	—	—	—	3			
Tamils ...	Males ...	—	1	1	2	4	—	1	—	2	—	—	16	16	16	100
	Females ...	—	—	—	—	—	—	—	—	—	—	—	—			
Moors ...	Males ...	—	—	4	3	1	3	—	—	1	—	—	12	12	11	91·7
	Females ...	—	—	—	—	—	—	—	—	—	—	—	—			
Malays ...	Males ...	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	Females ...	—	—	—	—	—	—	—	—	—	—	—	—			
Others ...	Males ...	—	—	—	—	—	—	—	—	1	—	—	1	1	1	100
	Females ...	—	—	—	—	—	—	—	—	—	—	—	—			

(18) *Work done by the Plague Staff during the Year 1930.*

Ward.	No. of Dwellings Claytonized.	No. of Dwellings Unroofed.	No. of Rat Holes Claytonized.	No. of Rats killed by Claytons.	No. of Recently Dead Rats found.	No. of Mummified Rats found.	No. of Dwellings Pesterined.	No. of Dwellings Disinfected.	No. of Rat Nests found.	No. of Cart Loads of Rubbish removed.
Fort ...	—	—	—	—	—	—	—	—	—	—
Pettah ...	6,887	6,887	7,402	476	14	4	2,064	4,842	12	296½
San Sebastian ...	1,802	1,802	2,042	74	—	—	1,396	379	3	107
St. Paul's ...	4,904	4,904	4,922	398	5	2	3,524	1,376	6	367¼
Kotahena ...	37	37	56	18	—	—	15	22	—	12½
Mutwal ...	976	976	1,147	121	4	2	578	398	3	192
New Bazaar ...	106	106	154	72	—	—	78	28	—	52¾
Maradana North ...	899	899	991	57	—	—	403	496	1	97½
Maradana South ...	357	357	240	61	2	—	162	195	3	82
Dematagoda ...	219	219	152	39	—	—	22	187	—	75¼
Slave Island ...	358	358	848	106	2	—	176	182	—	102½
Kollupitiya ...	107	107	305	56	—	—	91	16	—	33½
Bambalapitiya ...	88	88	73	37	2	—	42	45	—	14
Timbirigasyaya ...	8	8	8	4	—	—	5	3	—	1¼
Wellawatta ...	181	181	102	18	—	—	73	91	—	13
Cinnamon Gardens ...	—	—	—	—	—	—	—	—	—	—
Total ...	16,929	16,929	18,443	1,537	29	8	8,629	8,260	28	1,447

IX.—Smallpox and Vaccination.

There were two cases of smallpox in the city. One case in the person of a recent arrival from South India and the other case had acquired infection at the Mental Hospital, Angoda, where there was an outbreak about the middle of February among the attendants.

There were also three Port cases and one outside case.

(19) *Births and Primary Vaccinations.*

Year.	No. of Births.	Total Number of Primary Vaccinations performed in the City.	Deficit.
1923	7,107	6,192	915
1924	6,887	5,784	1,103
1925	7,663	5,704	1,959
1926	8,114	5,623	2,491
1927	8,491	4,545	3,946
1928	9,486	4,521	4,965
1929	8,658	7,398	1,260
1930	9,180	8,760	420

(20) *Vaccinations performed during the Year 1930.*

	Number of Primary Vaccinations.	Number of Re-vaccinations.	Total.
By Government Vaccinators	8,748	704	9,452
By the Public Health Department	12	493	505
Total	8,760	1,197	9,957

X.—Chickenpox.

The total number of town cases were 897, as against 1,288 in the previous year. There were also 5 Port cases and 90 extra-urban cases.

Though there were 7 cases in infants under one year of age and 3 cases in persons over 70 years of age; there were no deaths.

(21) *Chickenpox during the Year 1930.* (*Town Cases.*)

Monthly Incidence.

Month.	No. of Cases.	Month.	No. of Cases.
January	111	September	76
February	119	October	55
March	110	November	36
April	107	December	25
May	61		
June	51	Total	897
July	77		
August	69		

(22) *Chickenpox during the Year 1930.* (*Town Cases.*)

Racial Incidence.

Race.	No. of Cases.	Race.	No. of Cases.
Malayalees	351	Europeans	3
Sinhalese	344	Others	2
Tamils	128		
Burghers	37	Total	897
Moors	21		
Malays	11		

(23) *Chickenpox in Colombo Town during the Year 1930.* (*Town Cases.*)

Distribution according to Age.

Age Period.	No. of Cases.	Age Period.	No. of Cases.
Under 1 year	7	30 years and under 35	89
1 year and under 2	7	35 years and under 40	54
2 years and under 3	9	40 years and under 50	48
3 years and under 4	7	50 years and under 60	19
4 years and under 5	4	60 years and under 70	9
5 years and under 10	49	70 years and under 80	2
10 years and under 15	84	80 years and over	1
15 years and under 20	139		
20 years and under 25	227	Total	897
25 years and under 30	142		

XI.—Measles.

Measles showed a marked drop, there being only 134 town cases, as against 831 in 1929 and 612 in 1928.

The extra-urban cases numbered 4. There were no deaths.

(24) *Monthly Incidence of Measles. (Town Cases only.)*

Month.	No. of Cases.	Month.	No. of Cases.
January	6	September	—
February	7	October	7
March	8	November	2
April	50	December	2
May	40		
June	—	Total ...	134
July	9		
August	3		

(25) *Measles, Town Cases, 1930.—Distribution according to Age.*

Age Period.	No. of Cases.	Age Period	No. of Cases.
0 to 5 years ...	32	35 to 40 years ...	3
5 to 10 years ...	36	40 to 50 years ...	—
10 to 15 years ...	28	50 to 60 years ...	—
15 to 20 years ...	11	60 years and over ...	—
20 to 25 years ...	15		
25 to 30 years ...	4	Total ...	134
30 to 35 years ...	5		

XII.—Diphtheria.

There were 34 cases and 8 deaths reported during the year, of which 23 were town cases, 1 Port case, and 10 extra-urban cases. Of the 23 town cases, 4 cases ended fatally.

The majority, namely, 18, occurred in children under 10 years of age.

(26) *Diphtheria, 1930. (Exclusive of Port and Outside Cases.)*

Monthly Distribution by Race and Sex.

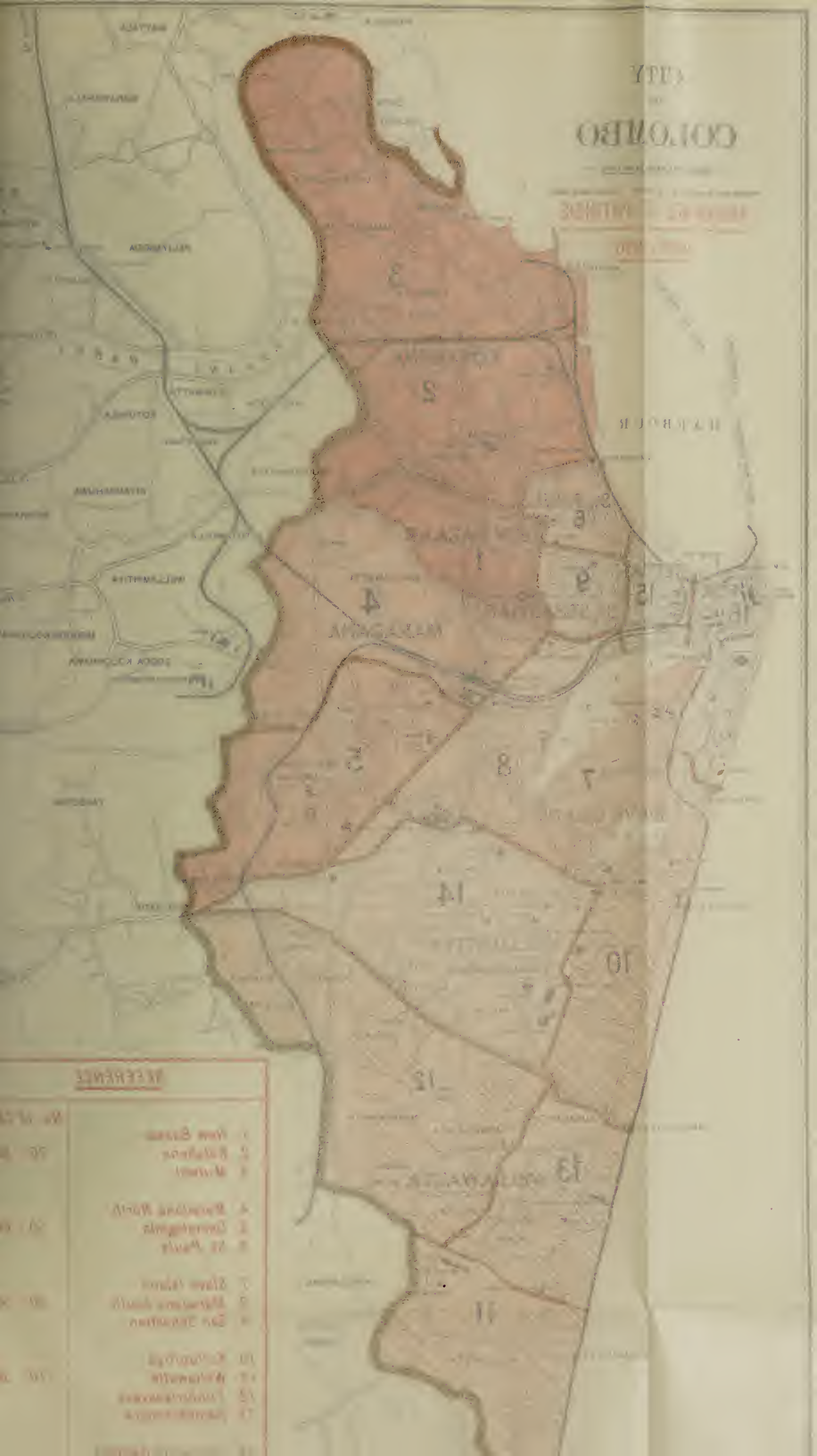
Month.	Europeans.		Burghers.		Sinhalese.		Tamils.		Moors.		Malays.		Others.		Total.
	Males.	Females.	Males.	Females.	Males.	Females.	Males	Females	Males.	Females.	Males.	Females.	Males.	Females.	
January	1	—	—	—	1	—	—	—	—	—	—	—	—	—	2
February... ...	—	—	—	1	—	—	—	—	—	—	—	—	—	—	1
March	—	—	—	1	—	1	—	1	—	—	—	—	—	—	3
April	—	—	—	1	—	—	—	—	—	—	—	—	—	—	1
May	1	—	—	—	1	—	—	—	—	—	—	—	—	—	2
June	—	—	—	—	—	1	—	—	—	—	—	—	—	—	1
July	—	—	—	—	2	1	—	1	—	—	—	—	—	—	4
August	—	—	—	—	—	—	—	—	—	—	—	—	1	—	1
September ...	—	—	—	2	—	—	—	—	—	1	—	—	—	—	3
October	—	—	—	1	1	—	—	—	—	—	—	—	—	—	2
November ...	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
December ...	—	—	—	—	1	2	—	—	—	—	—	—	—	—	3
Total ...	2	—	—	6	6	5	—	2	—	1	—	—	1	—	23
	2		6		11		2		1		—		1		

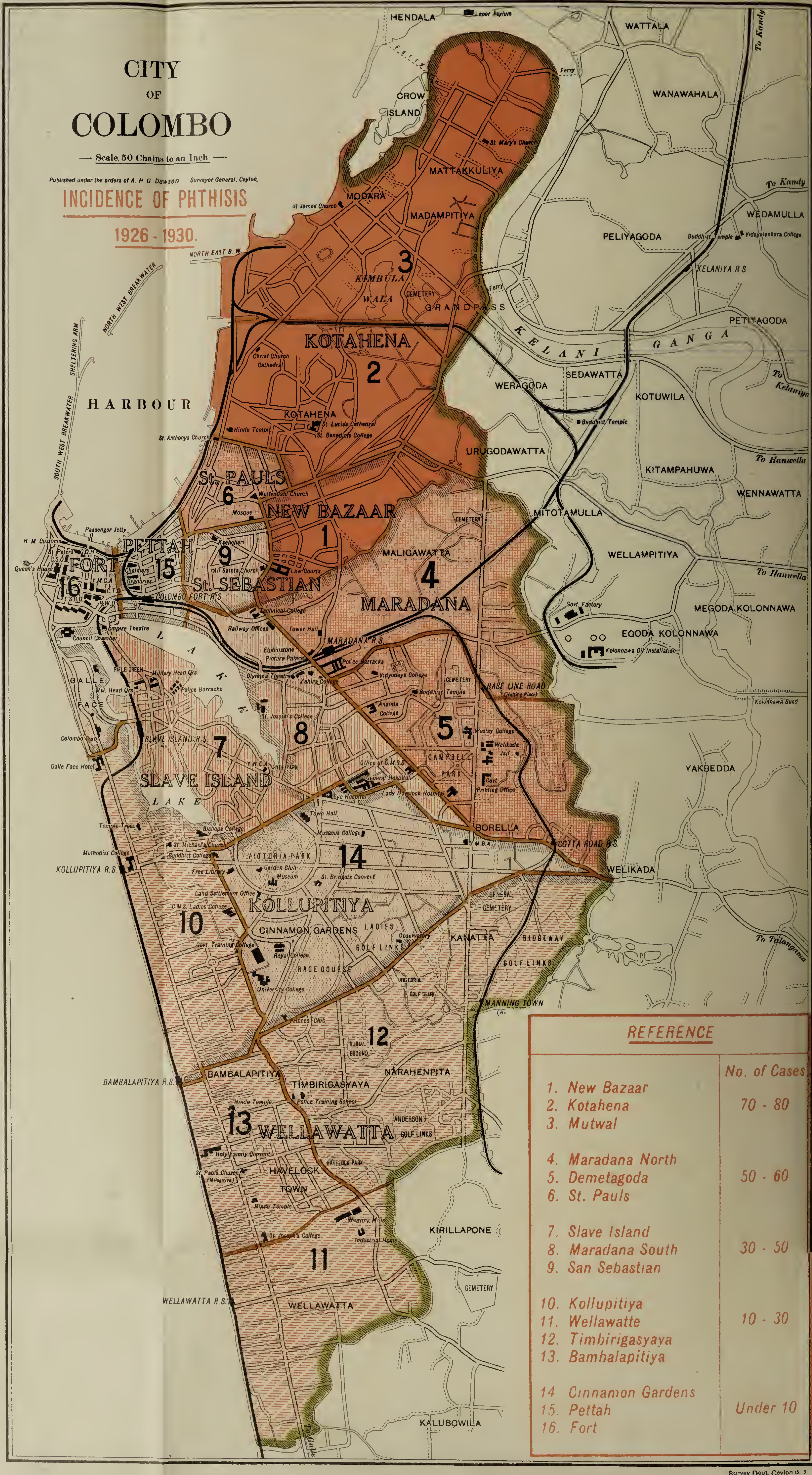
Port Cases ...	1
Beyond Limits ...	10
Total ...	34

XIII.—Whooping Cough.

There were 37 town cases and 2 deaths, as against 59 cases and 4 deaths in 1929.

With the 5 extra-urban cases the total number of cases was 42, as against 76 in 1929.





Survey Dept. Ceylon

XIV.—Tuberculosis.

Tuberculosis is the greatest and most difficult public health problem in every civilized country of the world. It is a problem not only to the sanitarian and the social worker but owing to its intimate and inseparable association with economic and social factors such as industrialism, wages, unemployment, poverty, housing, &c., it has become a national problem of the greatest importance and complexity to the State. In spite of the great strides taken in the West in matters of sanitation and public health, the disease has not been completely wiped out yet but still continues to levy a terrible toll of lives, being more deadly and expensive in its effect than war. Sanitary progress alone has not been sufficient to attack it. The social and economic factors with which it is connected have also to be taken into account in dealing with this problem if we are to make more rapid progress in fighting it. The disease is of world-wide prevalence ; between the years 1918 to 1927 it has been estimated that 40 millions have died of tuberculosis in the various countries of the world. In India over 6 millions are said to be affected by the disease and that over a million die annually. An astounding price to pay for the infringement of Nature's simple laws. For wherever man has departed from the natural and simple ways of life and has created for himself an artificial environment tuberculosis has arisen as the avenger to exact full payment. In every city and town of the civilized world where there is industrialism, crowding together of human beings, sweated labour, low wages, unemployment, alcholism, poverty, bad housing, &c., tuberculosis thrives and spreads and from the cities the surrounding villages become gradually infected. If in countries where great progress and reforms have been made in the sanitary, social, economic, and educational spheres the disease is still regarded as a scourge, what devastation must it cause in countries where such reforms are still in the primitive stages or not so advanced ! The disease being ordinarily one of fairly long duration, its victims drop off one by one unnoticed and its ravages do not strike the imagination as do the more rapidly operating epidemic diseases such as cholera, smallpox, or plague, which though more dreaded actually cause less destruction, less suffering, and less expense. Owing to this fact neither the State nor the people treat the problem of tuberculosis as a matter of urgent and prime importance and one that should be fought with all the resources and means at their command.

The Registrar-General's reports show that in the five years from 1925-1930 there were 17,902 deaths in the Island and 3,302 deaths in Colombo, and if we follow the general rule of reckoning the incidence at the rate of 10 cases to every death then during this period there must have been approximately 179,020 cases in the Island and 33,020 cases in Colombo, a state of affairs that should claim greater interest and attention from everyone interested in the welfare of the Island. The disease of tuberculosis, so called because of the little swellings or "tubercles" seen in the affected parts of the body, was known to the Chinese as early as the sixth century and was generally regarded until 50 years ago as a sort of inherited taint which led to gradual decay and death. This belief is still current ; the disinclination to notify the existence of the disease in a family being due to the fear that the whole family might be regarded as subject to degeneration and that the stigma so attached might work detrimentally specially in the matrimonial market !

Its infectious nature was definitely proved only when the causal agent, the tubercle bacillus, was discovered by Koch in 1881. The disease has been proved to depend upon the presence of this organism or germ which is found in all cases of tuberculosis in whatever part of the body the disease exists. Nearly every part of the body except the voluntary muscles are liable to attack, but the commonest seat is the lungs where it is called pulmonary tuberculosis or phthisis pulmonalis and in popular language "consumption."

The healthy human body has the power of destroying the vitality of the bacillus when introduced in small numbers, but where the infecting dose is great or the exposure to infection is prolonged and one's resisting powers are lowered in various ways, which will be dealt with later, the germ finds a suitable soil, gains a footing, and begins to propagate itself producing various morbid changes according to its location. The tubercle bacillus is found in enormous numbers in the sputum of patients suffering from advanced disease of the lungs. It has been estimated that the expectoration voided in 24 hours by a patient in such a stage may contain as many as 4 billion germs ! The germs are also found in the discharges from ulcerated glands, in the urine in case of diseased kidneys, in the fœces in intestinal tubercle, &c., but from the point of view of the spread of infection the sputum in the pulmonary form of the disease is the main source of infection.

The germ possesses considerable powers of resistance to external influences such as light, temperature, and dessication, and it is this property that makes it so dangerous. It cannot however live and retain its vitality indefinitely under unfavourable conditions. It needs passage through the human body for rejuvenation and renewal of vitality. It has been found by experiment that the dried spittle of a patient retains its virulence for from six to eight weeks while in moist dark places it may retain its virulence and be capable of reproducing the disease even after six months. Boiling or exposure to bright sunlight or strong disinfectants rapidly kills it.

From the point of view of prevention the following observations made by Dr. Soparkar of Bombay are interesting :—*

(1) Bacilli in sputum exposed to direct sunlight were alive for 6 hours but were dead after 8 hours.

(2) In sputum exposed to diffused daylight they were alive for 6 days but were dead after 8 days.

(3) In sputum kept in darkness, even when completely dessicated they were found alive and virulent for 309 days (10 months).

(4) From decomposing sputum bacilli were isolated after 20 days but not after 26 days.

(5) A pellet of sputum became sufficiently dried to be reduced to dust in 3 to 4 hours in direct sunlight and 3 to 4 days in diffused daylight.

(6) It was easier to reduce to dust sputum dried on dusty surfaces than on glazed surfaces.

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* "Vitality of tubercle bacilli outside the body." Indian Journal of Medical Research, 1917.

Dr. Soparkar draws the following practical conclusions :—

"It is evident from these experiments that there is an appreciable period after the complete drying of the sputum during which some of the tubercle bacilli contained therein remain alive. In the case of direct sunlight the time is approximately two hours ; this interval is not long, and the danger of infection from tuberculous sputum deposited in open places exposed to the sun cannot therefore be considered to be great.

"In the case of sputum deposited in a place exposed to diffused daylight, the interval during which sputum dust may remain infective can be calculated in days. But here, too, the tubercle bacilli soon lose their virulence, if the place be well lighted, the rate at which the tubercle bacilli become devitalized probably depending upon the intensity of the light.

"The danger of spreading infection is greatest when sputum is deposited indoors, especially in dark ill-ventilated places. In these conditions we have seen that tubercle bacilli may retain their vitality and power to cause disease as long as 309 days (10 months)."

Tuberculosis is a disease not only of man ; it affects cattle very extensively, and in certain Western countries cattle suffer far more than human beings and is a great problem to agriculturists and cattle owners and breeders. At first it was believed that man was immune to the bovine form, but the investigations of a British Royal Commission showed that infection from cattle was of frequent occurrence and that milk was the common medium by which infection was transmitted to man. The bacillus which causes bovine tuberculosis differs from the bacillus which causes human tuberculosis in certain respects and can be recognized by cultural and inoculation tests.

The bovine form of tuberculosis is said to be rare in North India and unknown in South India and it was believed to be so in Ceylon too until last year when a clear and well marked case was detected in a crossbred bull by Mr. Crawford of the Government Veterinary Department when he was acting Municipal Veterinary Officer. In order to ascertain whether there was greater resistance to tuberculosis on the part of Indian cattle as compared with English cattle careful investigations were made by Colonel Glen Liston and Dr. Soparkar of Bombay Bacteriological Laboratory and they report as follows :— *

"While the experiments of the Royal Commission on tuberculosis show that, with rare exceptions (1 out of 35) all English calves die of acute tuberculosis when inoculated with 50 milligrams of a culture of bovine tubercle bacillus, our experiments prove that at least 50 per cent. (6 out of 12) of Indian calves, whether they be buffaloe or cow calves, live for many days after a similar dose of culture of the bovine bacillus and when killed show only retrogressive or healing tubercular lesions.

"The experiment confirms the general experience that Indian cattle are less commonly affected by tuberculosis than English cattle are, and supports the view that the comparative infrequency of the disease among cattle in India is due to a natural resistance rather than to any method of housing or keeping cattle in India as compared with England."

It has also been found that crossbreeds in India were more susceptible to the disease than purely native breeds, the introduction of a European strain decreasing the resistance of the offspring.

Bovine tuberculosis as a source of infection in Ceylon may therefore be regarded as a non-existent or a very negligible factor in the spread of the disease. In Western countries the non-pulmonary or surgical forms of tuberculosis are stated to be mainly due to infection from bovine sources, milk being the principal medium, but in India, where surgical tuberculosis such as tubercular disease of glands, spine, joints, &c., is met with though not so commonly as in European countries, the infection is not from bovine sources but from human sources, and the same is no doubt true of Ceylon too where bovine tuberculosis must be regarded as absent or of extremely rare occurrence. Only phthisis or the pulmonary form of tuberculosis is notifiable in Colombo so that the incidence of the non-pulmonary forms cannot be stated, but figures obtained from the Registrar-General's death returns for the years 1927-1930 show (*vide* Statements 27 and 28)†—

(*a*) No evidence of increase in the number of deaths from non-pulmonary forms of tuberculosis.

(*b*) Non-pulmonary forms of tuberculosis form only 7·7 per cent. of the total number of deaths from all forms of tuberculosis.

(*c*) No marked difference in the incidence between males and females.

(*d*) That the commonest form of non-pulmonary tuberculosis is affection of the intestines and peritoneum.

(*e*) That next in order of frequency come the lymphatic system, meninges and central nervous system, disseminated tuberculosis and tubercular disease of the vertebral column.

* The susceptibility of Indian milch cattle to tuberculosis by Liston and Soparkar. Indian Journal of Medical Research, 1917.

† Classification of deaths prior to 1927 were based on the old international list and it is therefore difficult to compare the older figures with the more recent ones. Conclusions drawn from figures covering such a short period are not very reliable.

(27) *Deaths from all forms of Tuberculosis.*

Year.	No. of Deaths from Non-pulmonary Tuberculosis.	No. of Deaths from Pulmonary Tuberculosis.	Total Number of Deaths from all forms of Tuberculosis.
1927 ...	... 45 ...	... 594 ...	... 639
1928 ...	... 44 ...	... 597 ...	... 641
1929 ...	... 48 ...	... 593 ...	... 641
1930 ...	... 43 ...	... 583 ...	... 626

(28) *Deaths from Tuberculosis other than Pulmonary.*

	1927.			1928.			1929.			1930.		
	Males.	Females.	Total.	Males.	Females.	Total.	Males	Females.	Total.	Males.	Females.	Total.
Laryngeal tuberculosis ...	—	—	—	2	—	2	3	—	3	—	—	—
Tuberculosis of the meninges and central nervous system ...	3	—	3	2	—	2	4	3	7	4	3	7
Tuberculosis of the intestines and peritoneum	10	11	21	7	8	15	9	10	19	9	6	15
Tuberculosis of the vertebral column...	1	3	4	1	2	3	1	2	3	1	1	2
Tuberculosis of the joints ...	1	—	1	—	—	—	1	2	3	1	—	1
Tuberculosis of the skin and subcutaneous tissue	—	—	—	1	—	1	—	—	—	—	—	—
Tuberculosis of the bones (vertebral column excepted)	—	—	—	2	—	2	—	—	—	—	1	1
Tuberculosis of the lymphatic system (mesenteric and retroperitoneal glands excepted)	3	3	6	3	6	9	2	1	3	2	2	4
Tuberculosis of the genito-urinary system	—	—	—	—	1	1	1	—	1	—	1	1
Tuberculosis of other organs ...	4	2	6	4	2	6	—	4	4	6	5	11
Disseminated tuberculosis ...	2	2	4	1	2	3	1	4	5	1	—	1
Total ...	24	21	45	23	21	44	22	26	48	24	19	43

Source of Infection in Non-pulmonary Tuberculosis.

If bovine tuberculosis is the chief source of infection in non-pulmonary forms of tuberculosis in Western countries and if bovine tuberculosis is for all practical purposes non-existent in Ceylon, human tuberculosis must be the source of infection. How is the infection conveyed and by what medium ? The route of infection in this form of the disease is *viâ* the alimentary tract and in Western countries the infection is conveyed through the medium of milk which either contains the bacilli, or which has become infected from tuberculous lesions on the udders of affected animals. In Ceylon, cattle being free from tubercular disease, the milk when drawn contains no infective organisms and cannot therefore be incriminated as being the chief medium of infection, but this does not mean that milk does not become infected when stored in the house. As stated above infection is by ingestion and in Ceylon articles of food, including milk, become infected through the agency of flies and dust. We have seen above for what long periods of time tubercle bacilli retain their vitality in dark ill-ventilated rooms and when we take into consideration habits and practices such as indiscriminate spitting on the floor of the house, dry-sweeping of rooms, eating of food on the floor, prevalence of flies, and exposure of food to contamination by them we see how infection from human sources through infected food can enter the system *viâ* the recognized channel. Not only abdominal tuberculosis but other non-pulmonary forms can be caused by infection of the general circulation through the mucous membrane of the intestinal tract and the location of the disease in any particular site is probably determined by some local injury affecting its vitality or by the blocking of a small blood vessel (capillary embolism). Infection by this route, namely, *viâ* alimentary tract requires a larger dose of bacilli or a prolonged exposure to infection than is required for infection *viâ* the respiratory tract and this probably explains the reason for the small proportion of surgical tuberculosis as compared with pulmonary tuberculosis.

In Colombo, and I presume in Ceylon too, the non-pulmonary or surgical forms of tuberculosis cause, as we have seen above, comparatively less destruction than pulmonary tuberculosis and as the former results, so far as this country is concerned, from infection not from bovine sources but from human sources, the subject of pulmonary tuberculosis, which is more prevalent, more infectious, more dangerous and destructive requires careful study and will now be considered with the help of the available statistics under the following heads (A) Incidence, (B) Causes, and (C) Prevention.

A.—*Incidence of Pulmonary Tuberculosis in Colombo.*

Pulmonary tuberculosis was declared a notifiable disease in the year 1910.

1. *Incidence in the Town as a Whole.*—The following statement shows the number of cases, number of deaths, and the death-rate per 1,000 from 1911 to 1930 :—

Year.	No. of Cases reported.		No. of Deaths.	Death-rate per 1,000*		Remarks.
1911	585	Real Increase.	634	2·96	Average 3·05 per 1,000.	
1912	755		713	3·14		
1913	759		577	2·88		
1914	771		664	3·12		
1915	892		694	3·16		
1916	806	Apparent Increase.	750	3·42	Average 3·02 per 1,000.	Anti-Tuberculosis Institute opened.
1917	713		657	2·84		
1918	1,071		672	2·86		Influenza pandemic.
1919	1,285		705	2·95		
1920	1,361		729	3·02		
1921	1,367		737	3·02	Average 2·80 per 1,000.	
1922	1,181		640	2·58		
1923	1,343		727	2·90		
1924	1,204		679	2·69		
1925	1,146		719	2·81		
1926	977	Marked Decrease.	587	2·27	Average 2·23 per 1,000.	Appointment of Inspector of Insanitary Buildings. Mental Hospital transferred to Angoda outside city limits.
1927	810		594	2·27		
1928	910		597	2·26		
1929	902		593	2·21		
1930	918		583	2·15		

A study of the above figures would show that there was a real increase in the incidence between 1911 and 1915. Between 1916 and 1925 an increase is seen but is probably only apparent as it is not supported by the death-rate which shows a decrease from the quinquennial average of 3·05 per mille to 3·02 in the second quinquennium and to 2·80 in the third quinquennium. From 1926 to 1930 the decrease is fairly marked and is supported by the fourth quinquennial average of 2·23 per mille. The increase in the period between 1916 and 1925 being probably due firstly to the publicity given to this matter as a result of the report of the Tuberculosis Commission of 1911, the establishment of the Anti-Tuberculosis Institute in 1916 and consequent better diagnosis, earlier recognition, and improved notification and secondly to the influenza pandemic which probably brought to light many unsuspected, latent, and early cases of phthisis. In regard to the period between 1926 and 1930, the decrease was in a small measure due to the removal of the Mental Hospital to a site outside Colombo, which institution contributed 20 to 30 cases annually, but mainly to the general and progressive improvement of the sanitary conditions of the city. The appointment in 1925 of a whole-time Inspector to deal with insanitary buildings in the city and the action taken by him to render fit for habitation a large number of dwellings, viz., 4,405 insanitary dwellings from 1925–1930 was one of the most important steps taken and one which contributed very materially to the reduction in the incidence of the disease.

The death-rate which had been slowly declining since 1927 showed last year the lowest rate so far recorded, namely, 2·15 per 1,000. It must however be noted that the progress made is neither great nor satisfactory for in 20 years the rate has dropped by only ·81.

Of the nine principal towns of Ceylon, Colombo city has the highest death-rate. This is of course due to the fact that Colombo is the largest town in Ceylon and the housing and other conditions favourable to the generation and spread of the disease are naturally present in a greater degree in a large crowded town with slums than in a small town where the population is less concentrated and where slum conditions are absent or not so bad.

2. *Percentage of Total Deaths in Colombo.*—Pulmonary tuberculosis is one of the principal causes of deaths in Colombo and ranks second as a cause of death—Pneumonia being the first. During the period 1926–1930 the average percentage of the total deaths was 7·6.

(29) *Incidence of Pulmonary Tuberculosis by Wards, 1926 to 1930.*

Ward.	1926.	1927.	1928.	1929.	1930.	Total.	Quinquennial Average.
Fort	2	1	—	2	1	6	1
Pettah	4	6	9	4	9	32	6
San Sebastian	32	20	36	36	30	154	31
St. Paul's	49	41	38	51	71	250	50
Kotahena	71	57	61	79	89	357	71
Mutwal	64	67	67	72	87	357	71
New Bazaar	76	82	78	79	73	388	78
Maradana North	61	60	46	52	73	292	58
Maradana South	44	42	47	37	39	209	42
Dematagoda	45	43	69	44	52	253	51
Slave Island	66	45	39	39	46	235	47
Kollupitiya	26	22	17	12	18	95	19
Cinnamon Gardens	5	7	8	11	4	35	7
Bambalapitiya	14	9	19	6	12	60	12
Timbirigasyaya	21	17	8	12	15	73	15
Wellawatta	19	21	14	16	18	88	18
Vagrants and paupers	17	20	23	23	23	106	21
Untraced	361	250	331	327	258	1,527	305
Total Town cases	977	810	910	902	918	4,517	903

* This is the crude rate. Deaths of non-residents are included and deaths of residents outside are not included.

It is regrettable that the mortality incidence by wards is not available, but according to the number of cases the order of demerit is as follows :—

1. New Bazaar	7. Slave Island	13. Bambalapitiya
2. Kotahena	8. Maradana South	14. Cinnamon Gardens
3. Mutwal	9. San Sebastian	15. Pettah
4. Maradana North	10. Kollupitiya	16. Fort
5. Dematagoda	11. Wellawatta	
6. St. Paul's	12. Timbirigasyaya	

As is to be expected the densely crowded and insanitary areas of the town contribute the largest number of cases, whereas in the better residential districts where there is no crowding together of dwellings or of people the incidence is lowest. Pettah and Fort being mainly commercial areas there are no slums, hence the low rates. In the absence of mortality rates by wards it is not possible to make a definite statement, but there is reason to believe that some of the cases reported from the southern wards of the town such as Kollupitiya, Bambalapitiya, and Wellawatta are probably brought into these areas from elsewhere for the benefit of the sea air. (See Map No. 1.)

3. *Incidence by Streets.*—The list below shows the streets which had over 100 cases of pulmonary tuberculosis during the 20 years 1911–1930. It is remarkable that Dematagoda road which heads the list here also headed the list in respect of enteric fever (see annual report for 1929). An inspection made by the writer some years ago of all the houses in this street showed nearly 90 per cent. of them very bad from the point of view of lighting, ventilation, &c. Added to this there is overcrowding of houses and of people a good proportion of whom are Muslims whose peculiar customs tend to make bad sanitary conditions worse.

This list is a remarkably accurate guide to the congested and slummy areas of the town.

(30) *Streets which had over 100 cases of Pulmonary Tuberculosis during the 20 years, 1911 to 1930.*

Street.	Number of Cases.	Annual Average.	Street.	Number of Cases.	Annual Average.
Dematagoda road ...	348 ...	17	Forbes road ...	143 ...	7
Grandpass road ...	283 ...	14	Mutwal street ...	141 ...	7
Maradana Second Division ...	263 ...	13	Maligawatta ...	140 ...	7
Jampettah street ...	256 ...	13	San Sebastian street ...	139 ...	7
Wolfendahl street ...	237 ...	12	Temple road, Dematagoda...	133 ...	7
Piachaud's lane ...	202 ...	10	Church street, Slave Island...	123 ...	6
Gintupitiya street ...	200 ...	10	Messenger street ...	120 ...	6
Modera street ...	197 ...	10	Vincent street ...	120 ...	6
Layard's broadway ...	195 ...	10	Siripina lane ...	117 ...	6
Alutmawata road ...	195 ...	10	Pickering's road ...	113 ...	6
Silversmith street ...	186 ...	9	Maradana First Division ...	111 ...	6
Kochchikadde street ...	183 ...	9	Wellawatta road ...	104 ...	5
Wall street ...	165 ...	8	Santiago road ...	104 ...	5
Ferry street ...	148 ...	7	Steuart street, Slave Island...	103 ...	5
Maradana Third Division ...	147 ...	7	Skinner's road south ...	102 ...	5

4. *Incidence by Race and Sex.*—Taking first the racial incidence for the last five years we find that the Sinhalese are the chief sufferers, the average death-rate for the five years being 2·77 ; next come the Malays 2·59, then the Moors 1·91, then the Tamils 1·80, Others (Malayalees, Pathans, &c., are included under this head) 1·45, Burghers 1·31, and lastly Europeans ·65.

The Sinhalese form the major part of the population and the high rate is due to the conditions under which the poorer classes live in the crowded quarters of the town. The Malays and Moors are Muslims and their rates (taken together 1·99 or separately 1·91 and 2·59 respectively) are higher than the Tamil rate. The high rate among the Muslims is due, *inter alia*, to the custom (among the poorer classes who live in small houses without surrounding garden) of keeping all external windows and doors closed in order to secure privacy and seclusion for their females. By shutting out fresh air and sunlight, the two great natural enemies of the tubercle bacillus, they create an atmosphere and environment conducive to the lowering of their own body resistance to disease and to the preservation of the vitality of the disease-causing germ. The Malays, though Muslims by religion, are less strict in keeping purdah, but their rate is very much higher than that of the other Muslim community, the Moors. The reason for this is difficult to understand—it may possibly be due to a greater susceptibility or to lowered physical stamina due to indulgence in drugs, alcohol, &c., or to intermarriage practised over a considerable period among members of a numerically small community. The very low European rate is due to their better economic position which enables them to live in good and healthy surroundings and also to the fact that any of them afflicted with the disease get away as a rule to their own country or to some European sanatorium.

Taking the sex incidence next we find, from Statement 31 below, that the incidence of the disease is higher among females than among males in the case of the Burghers, Sinhalese, Moors, and Malays. In the case of the Burghers and Sinhalese the incidence is practically equal, the females showing a slightly higher percentage, but among the Muslims and particularly among the Malays the difference is fairly marked. In the case of the Europeans, Tamils (Indian Tamils are included under this head), and "Others" the markedly lower female percentage is partly due to the fact that females of these races when affected by this disease return to their homes in Europe or India for treatment or to die among their "ain folk."

The higher percentage among females generally is due to the fact that they are more at home, have less opportunities for outdoor recreation, and are more exposed to infection by direct contact with a patient owing to the duties of tending and nursing that naturally devolve upon their sex.

(31) *Number of Deaths from Pulmonary Tuberculosis, 1926 to 1930.*

Distribution by Race and Sex.

Race.	1926.		1927.		1928.		1929.		1930.		Total.		Both Sexes Total.	Percentage among Females.
	Males.	Females.	Males.	Females.	Males.	Females.	Males.	Females.	Males.	Females.	Males.	Females.		
Europeans ...	2	—	3	1	—	—	2	1	1	—	8	2	10	20·0
Burghers ...	9	9	13	12	6	10	9	8	15	15	52	54	106	50·9
Sinhalese ...	191	167	166	190	155	170	177	185	156	163	845	875	1,720	50·9
Tamils ...	68	30	52	36	75	69	56	32	66	45	317	212	529	40·1
Moors ...	40	39	33	48	40	36	39	50	43	43	195	216	411	52·6
Malays ...	7	10	11	10	4	10	7	8	6	9	35	47	82	57·3
Others ...	11	4	15	4	18	4	15	14	17	4	76	20	96	20·8
Total ...	328	259	293	301	298	299	305	288	304	279	1,528	1,426	2,954	48·3

(32) *Racial Death-rates.*

Race.	1926.	1927.	1928.	1929.	1930.	Average, 1926-1930.
Europeans ...	0·67	1·32	—	0·96	0·32	0·65
Burghers ...	1·14	1·57	0·99	1·04	1·82	1·31
Sinhalese ...	2·95	2·90	2·62	2·88	2·51	2·77
Tamils ...	1·71	1·52	2·45	1·48	1·85	1·80
Moors ...	1·88	1·90	1·77	2·05	1·95	1·91
Malays ...	2·74	3·35	2·21	2·34	2·31	2·59
Others ...	1·16	1·46	1·67	1·39	1·56	1·45
Moors, Malays } Muslims ...	1·99	2·08	1·82	2·08	2·00	1·99

5.—*Incidence by Age Periods.*—

(33) (*a*) *1930.*

Age Period.	No. of Cases.	No. of Deaths.	Age Period.	No of Cases.	No. of Deaths.
0 to 5 years ...	11	6	30 to 35 years ...	138	43
5 to 10 years ...	7	1	35 to 40 years ...	84	42
10 to 15 years ...	20	10	40 to 50 years ...	147	78
15 to 20 years ...	82	36	50 to 60 years ...	63	32
20 to 25 years ...	169	70	60 years and over ...	44	31
25 to 30 years ...	153	58			

(*b*) *1929.* (Figures obtained from Anti-Tuberculosis Institute returns.)

Age Period.	No. of Cases.	No. of Deaths.	Age Period.	No. of Cases.	No. of Deaths.
0 to 5 years ...	6	Not available.	30 to 35 years ...	63	Not available.
5 to 10 years ...	4		35 to 40 years ...	54	
10 to 15 years ...	9		40 to 50 years ...	61	
15 to 20 years ...	34		50 to 60 years ...	27	
20 to 25 years ...	66		60 years and over ...	20	
25 to 30 years ...	75				

(*c*) *1928.* (Figures obtained from Anti-Tuberculosis Institute returns.)

Age Period.	No. of Cases.	No. of Deaths.	Age Period.	No. of Cases.	No. of Deaths.
0 to 5 years ...	—	Not available.	30 to 35 years ...	26	Not available.
5 to 10 years ...	6		35 to 40 years ...	27	
10 to 15 years ...	2		40 to 50 years ...	29	
15 to 20 years ...	24		50 to 60 years ...	16	
20 to 25 years ...	43		60 years and over ...	14	
25 to 30 years ...	38				

The period covered is too short for any correct conclusions to be drawn, but from the above figures it would appear that during the age period 20 to 30 years the largest number of cases and deaths occur.

6. *Incidence by Occupation.*—Unfortunately no accurate or reliable statistics are available under this head. A study of 358 records for the years 1928 and 1929, obtained through the courtesy of the Medical Superintendent of the Anti-Tuberculosis Institute, shows persons engaged in the following occupations or trades to be chiefly affected :—

	Cases.		Cases.
Labourers ...	121	Hospital servants ...	6
Mechanics ...	93	Teachers ...	4
Shop employees ...	68	Policemen ...	4
Domestic servants ...	33		
Tailors and weavers ...	17	Total ...	358
Boatmen ...	12		

The period covered is too short and the figures are too few to draw any reliable conclusions from but the following observations are, I think, justified. The high rate among labourers is due not so much to the nature of their occupation as to the home conditions of this stratum of the community. By reason of low earnings, hard work, exposure, poor food, and bad housing they are of all classes most liable to infection. In the next group, mechanics, in which are included masons, metal workers, printers, blacksmiths, &c., the nature of the occupation is undoubtedly a contributing factor. In the case of shop employees infection is probably due to close contact during hours of work with an open or infectious case of tuberculosis. In the case of tailors and weavers the nature of the occupation (the atmosphere of the work room, the restricted movements of the chest, &c.) plays probably an important rôle. Hospital servants, by nature of their work, are exposed to prolonged and concentrated infection. In the case of boatmen, frequent wetting, exposure, &c., probably causes chest complaints such as bronchitis, pleurisy, and pneumonia which when neglected end in tuberculosis of the weakened lungs.

7. *Monthly and Seasonal Incidence.*—The following statements show the incidence by months and by seasons, wet and dry, for the last five years. There would appear to be no remarkable monthly or seasonal variation in the incidence of the disease :—

(34) *Monthly Incidence.*

Month.	1930.	1929.	1928.	1927.	1926.	Average.
January	79	81	85	76	122	88·6
February	49	58	82	68	77	66·8
March	77	58	76	72	73	71·2
April	66	74	76	73	79	73·6
May	91	90	89	54	77	80·2
June	83	69	80	65	74	74·2
July	78	71	71	60	92	74·4
August	88	90	83	77	88	85·2
September	73	92	64	61	75	73·0
October	99	96	62	65	82	80·8
November	69	73	78	80	80	76·0
December	66	50	64	59	58	59·4
Total	918	902	910	810	977	

(35) *Seasonal Incidence.*

		1926.	1927.	1928.	1929.	1930.	Total.
Wet Season	Total for April, May, June, September, October, and November	467	398	449	494	481	2,289
Dry Season	Total for January, February, March, July, August, and December	510	412	461	408	437	2,228

B.—*Causes of Pulmonary Tuberculosis.*

(*a*) *Specific Cause.*

Pulmonary tuberculosis or any other form of it is not a hereditary disease. No child is born with it. It is caused by a specific organism, the tubercle bacillus. We have seen how it is broadcast by patients in an active stage of the disease (4 billions in 24 hours) and how the germ can retain its vitality and infecting power for months under certain favourable conditions of temperature and darkness. The causative germ may be regarded as omnipresent in any city and that infection is common and widespread.

It is estimated that about 70–90 per cent. of the population of a city is infected by it though only a small percentage of those infected become diseased. The body in health possesses certain properties that can resist and destroy the invading germs of disease but when these natural defensive powers are weakened or destroyed then the invading hosts of disease gain entrance and settle down in the body producing the signs and symptoms of disease.

The factors that prepare the soil and favour the implantation and growth of the germ are numerous and may now be considered briefly.

(*b*) *Contributing Factors.*

1.—PERSONAL :—

(*a*) *Inherited Weakness of Constitution.*—Though tuberculosis is not hereditary an inherited weakness of constitution does render an individual liable to fall an easy victim to the disease. Such constitutional weakness may be seen in the offspring of small communities practising close intermarriage for reasons of race, caste, or property ; of debauched alcoholic or too youthful or aged parents, &c.

(*b*) *Acquired Weakness of Constitution.*—Enfeeblement of the body may be caused by—

(1) *Faulty Feeding.*—Wholesome nutritious food, sufficient in quantity and well balanced as regards the various components is necessary during the years of growth and early adult life. This question of proper feeding is naturally associated with the question of poverty and wages. The greater incidence among the labouring classes is partly due to malnutrition, the result of low wages and consequent inability to purchase sufficient food of good quality.

(2) *Overwork or Long Hours of Work.*—Causes bodily exhaustion. Opportunities for rest and recreation in the open air are denied or limited.

(3) *Alcoholism and Addiction to Drugs.*—These habits have an injurious effect upon the resisting powers of the body. A study of the records of 580 cases in 1928 and 1929 obtained from the Anti-Tuberculosis Institute gives the following information :—

Abstainers	429
Moderate drinkers ...	112
Heavy drinkers	39
	580

The percentage works out at 74 per cent. abstainers and 26 per cent. drinkers (taking moderates and heavy together). To what extent alcohol contributed to the weakening of the body we cannot say definitely but there can be no doubt that it is a contributing factor.

(4) *Certain Diseases.*—Pulmonary tuberculosis supervenes after certain diseases which cause enfeeblement of the body in general, *e.g.*, Enteric Fever, Chronic Malaria, Syphilis, &c., or of the lungs in particular, *e.g.*, Pleurisy, Pneumonia, Influenza, Whooping Cough, &c. From a study of 480 cases in 1928 and 1929 obtained from the Anti-Tuberculosis Institute a previous history of the following diseases is given :—

	Cases.		Cases.
Influenza ...	in 378	Fever ? ...	in 6
Enteric fever ...	in 38	Asthma ...	in 3
Malaria ...	in 36	Cough (Bronchitis ?) ...	in 3
Pneumonia ...	in 9	Injury to chest ...	in 3
Whooping cough ...	in 2		
Dysentery ...	in 2		480

(5) *Ignorance.*—Ignorance of the simple laws of personal and community hygiene and of the nature and mode of infection is another contributing factor.

2.—Bad Habits :—

(*a*) *Spitting.*—The chief medium of infection is the expectoration from "open" cases of pulmonary tuberculosis. The habit of indiscriminate spitting must be regarded as a most dangerous practice and one that helps to spread the infection widely. The practice of chewing tobacco and betel leaf conduces to the abnormal flow of saliva and wherever one goes one sees people squirting saliva all over the place. Dr. Soparkar's experiments have shown that sputum voided in open places—such as streets, &c., exposed to bright sunlight is not so dangerous as sputum voided in places where sunlight has no access. Spitting therefore inside buildings—railway carriages, &c.—is attended with great danger to others.

(*b*) *Kissing* may be a delightful pastime, but is attended with serious risk of infection especially when kisses are imprinted on the mouth.

(*c*) *Coughing and Sneezing* without covering the mouth and nose with a handkerchief are dangerous to others as particles of saliva in the form of minute droplets are jetted into the air and people within a radius of three feet or more can be infected. This is a very common and dangerous mode of infection as the bacilli from the sick are transmitted directly to the healthy without any deterioration outside the human body.

(*d*) *Use of common Vessels for Food or Drink.*—Unless these are carefully cleansed infection can be transmitted to the healthy. The use of common vessels in schools, places of public entertainment, &c., are open to this objection.

(*e*) *Sleeping with Windows closed.*—Many people have a dread of night air. They perhaps imagine that its composition changes after nightfall and so shut themselves up at night. It is not only the ignorant classes who do this but also those who are better educated and ought to know better. An early morning walk along the roads of Cinnamon Gardens will show a very large number of bedroom windows carefully closed for the night. As the majority of Colombo bungalows have barred windows the object of closing them is not so much to exclude burglars as to exclude night air. This practice of sleeping in a close atmosphere vitiated by the exhalations of the inmates conduces to the weakening of the lungs and the bodies. Pure fresh air is the life of the body and only those who are accustomed to sleep with windows wide open appreciate its great value.

(*f*) *Sleeping with Head covered.*—This is more dangerous than even sleeping with windows closed. I have often seen servants sleeping on the verandahs at night with the head and body completely enveloped in an outer sheet or cloth. This is perhaps done to escape bites of mosquitoes but it is a practice that is most harmful. It is extraordinary how after a time people can get accustomed to and tolerate foul air ! During morning inspections the writer has frequently been in dwelling rooms where the air has been disgustingly foul but the inmates of which seemed quite comfortable and happy. The breathing of foul air must undoubtedly lead to gradual deterioration of the health and lowering of natural vitality and resisting powers.

3.—Social :—

Purdah.—We have seen in the section dealing with incidence by race and sex that the Muslim communities practising purdah have a high death-rate and that the females of these two communities suffer very much more than the males. This is undoubtedly due to the practice of keeping women secluded in their homes without exercise and the opportunities of enjoying the life-giving fresh air of the out-of-doors. In this respect it is the middle class who are the greatest sufferers. The poorer classes are compelled to go out and work in the open air and the richer classes have the advantage of private gardens, but the females of this community as a whole have less freedom and opportunities of going out and therefore spend most of their time indoors engaged in sedentary work which conduces to softness, obesity, and weakness of the body.

4.—Economic :—

(1) *Low Wages and High Price of Food.*—We have seen that faulty feeding is the cause of malnutrition and weakening of the constitution. Low wages and high prices of foods, particularly milk, eggs, meat, ghee, &c., naturally lead to consumption of insufficient food or articles low in food values. In the early years of life milk and other nutritious foods are necessary for growth and health, but the poorer classes cannot afford these and many of them suffer from underfeeding which renders their bodies susceptible to infection and disease.

(2) *Low Wages and High Rents.*—Owing to the inadequacy of suitable dwellings for the working classes and the high rents demanded for what is available many of the labouring classes live crowded together in dwellings which, owing to the demand in the past when there were no building regulations, had been divided and sub-divided and added to so as to render them utterly unfit for human habitation by reason of the lack of light and ventilation and means of drainage, &c.

This overcrowding of persons and buildings naturally led to obstruction to light and free circulation of air, fouling of the soil, vitiation of the air inside and outside, and increased and greater personal contact. When cases of pulmonary tuberculosis occurred in such dwellings and the sick were not segregated but allowed to sleep with the healthy in a common room, a dark corner of which was used for voiding the expectoration, infection was easily spread from the sick to the healthy. Among the conditions which are responsible for the high incidence of the disease housing conditions of the people are the most important. It was in the close ill-ventilated overcrowded tenement-dwellings of the slums that pulmonary tuberculosis was born and bred and disseminated.

5.—Environmental :—

(1) *Climate.*—The prevalence of tuberculosis in any area depends chiefly upon the degree of infection present, but climate has a certain effect upon the general health. According as the climate of a place is bracing or enervating the health of the people is said to be generally good or bad. A dry climate with a low mean temperature is generally admitted to be the most healthy and comfortable, and conversely a very humid climate with a high mean temperature as unhealthy and uncomfortable. The climate of Colombo combining as it does a high mean humidity of 80 per cent. with a high mean temperature of 80·5 is one that is not conducive to the maintenance of vigorous health or to the treatment of pulmonary tuberculosis which requires a dry climate, low mean temperature, and small rainfall.

(2) *Urbanization.*—Tuberculosis is much more prevalent in cities than in villages, and in cities it is in direct proportion to the density of population, congestion of dwellings and overcrowding of dwellings, presence of factories, slums, dust, &c. Colombo, the largest city in the Island, has the highest incidence.

(3) *Atmosphere.*—A dusty atmosphere is injurious to health, but from the point of view of pulmonary tuberculosis the nature of the dust is important. "Dust" plays two rôles: it may injure the delicate lung tissue or it may act as a vehicle for the transmission of disease germs. Ordinary soft dust as from gravelled roads, plumbago, coal, &c., does not injure the lung tissue but dust from metalled roads containing hard sharp particles does injure the lung tissue. We have seen in one of the preceding sections location of the disease is often determined by some local weakness or injury and an injured lung may easily become the starting point of tuberculosis of the lungs. As a matter of fact pulmonary tuberculosis is fairly common among stone cutters, &c., in Western countries, but statistics are not available here to show what effect such occupation has upon the incidence of the disease. Dust may also act as a vehicle for conveying the germ. Dr. Soparkar's experiments would show that the danger of infection from tuberculosis sputum deposited in open spaces such as public streets exposed to the sun is not so great as when the sputum is deposited inside buildings where the effect of sunlight is not felt. Street dust would therefore appear to be less dangerous than the dust of factories, workshops, public buildings, conveyances, dwelling houses, &c.

(4) *Dampness of Soil.*—Dampness of soil and consequent dampness of dwellings is admittedly bad for one's health. Owing to the high level of sub-soil water, high rainfall, inadequate drainage in some areas, and general absence of damp-proof courses, "dampness" is a common feature of most houses, particularly of those cheaply built ones occupied by the poorer classes. Continuous exposure to dampness predisposes one to respiratory diseases such as coughs and colds, &c., which lower the vitality and weaken the lungs.

C.—*Prevention of Tuberculosis.*

Preventive measures should be directed towards—

(*a*) The destruction of the specific cause of the disease, and
(*b*) The abolishment or mitigation of the contributory factors.

(*a*) *The Destruction of the Specific Cause.*

So far as this country is concerned the specific cause lies in the human body which acts as a reservoir for the supply of germs. If the human sources of infection can be controlled, the incidence of this disease would be considerably reduced. We have seen that the non-pulmonary forms of tuberculosis, from the point of view of spread of infection, are of comparatively little importance and that "open" cases of pulmonary tuberculosis where daily output of germs runs into billions are the most dangerous. In order to prevent such cases from becoming a source of infection to the healthy all cases of pulmonary tuberculosis should be detected and reported early so that suitable treatment and a proper régime might be adopted with a view to prevent the case progressing towards the active stage when germs are thrown out to the danger of others.

Early Detection.—This can be most effetively done by periodic health examinations which would bring to light early cases of the disease. All children of school going age should be periodically medically examined. Tubercular infection is usually acquired in childhood and usually manifests itself in the form of enlarged glands and such cases should be suitably treated. All Government and Municipal servants, employees of business establishments, factories, workshops, &c., should be required to produce at the beginning of every year a clean bill of health. These periodic health examinations would disclose not only tubercular infection but other diseases such as cancer, diabetes, &c., which begin insidiously and which can be cured if taken in hand early. In America these periodic health examinations are becoming popular as a result of propaganda by Life Insurance Companies, Health Organizations, &c., and are an excellent means of detecting disease in its earliest stage. If people would only realize the benefit to themselves and to the community of such regular medical examinations how greatly would the span of life be prolonged ! Until the time such a sound practice becomes general and voluntary I feel that all employers would be justified in demanding such a certificate of good health from their employees. Very frequently infection is acquired in the office or workshop, through the presence of a fellow worker in an infectious stage of the disease. It is to the interest of the employer and the other workers to have such a person removed.

Next to the regular medical examination, cases could be detected early if competent medical opinion were sought at the earliest appearance of signs and symptoms. Most people are not aware of the early signs and symptoms of the disease and wait until a hacking cough disturbs sleep at night. Even then few would seek competent advice. Much money is wasted on lung tonics and other patent nostrums and many quacks consulted before competent advice is sought.

An examination of 630 records of the Anti-Tuberculosis Institute shows the stage of disease when patients sought advice at the Anti-Tuberculosis Institute.

Stage I.	Incipient	5 cases.
Stage II.	Physical signs present... ...	125 cases.
Stage III.	Physical signs marked... ...	486 cases.
Stage IV.	More advanced with cavities ...	12 cases.
	Miliary tuberculosis	2 cases.
	Total ...	630

From stage II. onwards bacilli may be found in the expectoration. These figures show that competent advice is not sought early enough when the chances of recovery are greatest and the danger of infecting others is least. The early signs and symptoms of the disease should be made known to the public more widely by various health publicity methods.

Early Notification.—Pulmonary tuberculosis has been a notifiable disease since 1910, but there is reason to believe that a large number of cases still escape notification, due either to the fact that qualified medical men are not consulted, or to a fear to disclose the nature of the disease because of the imaginary stigma of family taint.

The following figures are interesting as showing the large proportion of cases that escape notification which means that neither suitable treatment nor precautionary measures against conveying the infection to others had been taken :—

Year.	Total number of Cases.	Notified before Death.	Notified after Death.
1926	977	805	172
1927	810	611	199
1928	910	689	221
1929	902	674	228
1930	918	687	231

Isolation.—The ideal to be aimed at, if we are to control the dissemination of infection, is the isolation and proper treatment of all cases at the earliest recognition of the disease when the chances of complete recovery are greatest, but the isolation of all the sick, having regard to the large number of people affected, is an impracticable proposition. Adequate accommodation should, however, be available at the Sanatorium for all indigent cases that seek admission. When we come to the question of dealing with the more advanced stages of the disease, the active open cases, we are faced with a most difficult problem. Should all active cases be compulsorily isolated ? If we compulsorily isolate persons suffering from comparatively harmless infectious diseases like chickenpox and measles there is greater reason for persons suffering from a more dangerous disease like phthisis to be isolated. But the problem is how long are these cases to be isolated taking into consideration the long duration of the illness and the large numbers affected ? From the point of view of public safety the answer is, until cured or until death. This would of course require very extensive hospital accommodation and the expenditure of large sums of money which the country cannot afford.

The "active" cases may be divided into two classes :—

(1) Hopeful cases with a fair prospect of recovery under suitable treatment and régime, and

(2) Hopeless cases, too far advanced and certain to die.

Early cases and "hopeful" cases go either to the Kandana Sanatorium or Ragama Hospital according as the Medical Superintendent of the Anti-Tuberculosis Institute directs, but what of those "hopeless cases"? Some go to the phthisis wards of the General Hospital and others continue to live on in their homes infecting all around them until death releases them from their sufferings. It is this class that should be compulsorily isolated until death, but before such a measure can be enforced adequate accommodation should be provided. In the opinion of the writer it is the duty of the Council to establish and maintain a hospital for all such town cases in a suitable place, preferably on the outskirts of the town or at Angoda. There is yet another problem. The institutions at Kandana and Ragama discharge patients when they are cured or when the disease has reached a quiescent inactive stage but no provision has yet been made for the after-care of these people. They come back to the miserable homes in which they were infected, to the same old surroundings and environment and many of them back to the same calling or trade. True, during their stay at the sanatorium they had learned the importance of fresh air, of sleeping with open windows, eating good food, disinfecting sputum, &c., but when they return to their old surroundings, with all the will in the world to follow the excellent régime taught them, they are unable to do so by circumstances over which they have no control. How can they obtain fresh air and sleep with open windows when half a dozen are crowded into one room and there is perhaps no window at all to open or if there is one it opens on to a foul smelling alley ? How can they obtain nourishing food, eggs, milk, &c., when their earnings are not sufficient or their means have been further reduced by a long illness ? All the advice, treatment, and care given at the sanatorium are lost, there is recurrence of the disease and their last state is worse than their first. This description of course applies to the poorer classes. The better classes benefit greatly by the treatment and correct régime at the sanatorium and return home and practice what they have been taught. But as we are concerned with the poorer classes who are the greatest sufferers from the disease the question of after-care is one of great importance. If treatment at the sanatorium is not followed up money spent upon these cases is not employed to the best advantage. A garden or farm colony should therefore be established where poor people after sanatorium treatment could find suitable employment in open air surroundings. As such a colony cannot be expected to be self-dependent it will have to be subsidized by the State. This problem must be faced some day and the sooner it is done the sooner will real and full benefit be reaped from sanatorium treatment.

(*b*) *Abolishment or Mitigation of the Contributory Factors.*

(1) *Weak Constitution.*—A weak constitution inherited or acquired is susceptible to disease. Weakly children particularly of tubercular parents constantly exposed to infection run grave risk of becoming diseased themselves. They should be removed from such an environment if they are to be saved from disease. For this class of child a "preventorium" is required where they could be brought up under healthy surroundings, their physique and resisting powers built up, and where they could be educated in open air class rooms.

(2) *Malnutrition due to Poverty, Long Hours of Work, Alcoholism, Purdah, &c.*—These are economic and social problems outside the scope of this article, but they are factors which cannot be ignored.

(3) *Ignorance of the Laws of Health, Bad Habits, &c.*—These can only be effectively combatted by making the teaching of hygiene and physiology compulsory in all schools and particularly in girls' schools. The dangerous practice of indiscriminate spitting is one that requires serious notice. The habit of betel leaf and tobacco chewing conduces to spitting and until people are better acquainted with the dangers of indiscriminate spitting, so long will the practice continue. It is a punishable offence to spit in public buildings and conveyances but the law is almost a dead letter except in Municipal markets. Inside public buildings and conveyances, &c., one sees obvious signs of this practice. The danger is great in these cases as the disinfecting power of sunlight has no play. The use of coir rugs and matting in all public places should be done away with so also spittoons containing sand, coir dust, &c., and in place of these enamelled buckets containing a solution of strong disinfectant should be placed in suitable places for people to spit into. These could be emptied daily by the sweeper into a gully or lavatory pan. The attempt to prevent spitting by notices is futile. It is better to recognize the evil and to provide for it. The disinfection of all buildings where the public congregate in large numbers such as railway stations, the law courts, theatres, banks, post offices, public conveyances, &c., should be regularly disinfected at least once a week and all sweeping should be done after sprinkling the floor with water or moist coir-fibre dust.

(4) *Overcrowding.*—This is a problem of housing. We have seen that tuberculosis is in direct proportion to density of population. In addition to the improvement of existing dwellings, which is steadily being pursued by this Department, more dwellings of a better type and cheaper in rent are required. It is a mistake to attempt housing within the city. The motor bus has solved the problem of travelling to a very great extent. Large undeveloped areas are available just outside the city limits. These could be purchased cheap and a healthy garden city developed. The problem of overcrowding, which is one of the most important contributory factors, cannot be tackled until more housing accommodation is provided for those dehoused.

(5) *Environmental Factors.*—Unfortunately climate cannot be changed. Early cases of surgical tuberculosis might benefit by the sea air but for the treatment of pulmonary tuberculosis the climate of Colombo is most unsuitable.

Dusty Atmosphere.—The dust nuisance has been abated very considerably by the substitution of tar macadam roads for the soft gravelled roads. Further improvement can be effected by flushing the roads with water at regular intervals. Road dust, though it does vitiate the atmosphere, is not so dangerous a factor as dust from the inside of buildings.

Dampness of Soil and Buildings.—Better drainage of low-lying areas and provision of damp proof courses in all dwellings are required.

In conclusion mention may here be made of the measures that have already been taken and which have had a most beneficial effect on the mortality from this disease and the further measures that should be taken in the future to complete the good work already done.

Measures already taken :—

(1) Pulmonary tuberculosis was declared a notifiable disease in 1910.
(2) Spitting in public places and public conveyances was made a punishable offence in 1910.
(3) An Ordinance to amend the law relating to the housing of the people and to provide for the improvement of towns was passed in 1915.
(4) The Anti-Tuberculosis Institute was established in 1916.
(5) Ragama Hospital for advanced cases was opened in 1917.
(6) A whole-time Inspector to deal with Insanitary Buildings was appointed in 1925.
(7) A sanatorium at Kankesanturai was completed this year but for lack of funds this institution has not been opened to the public yet.

Future Measures :—

(1) A preventorium for susceptible poor children.
(2) A farm or garden colony for the after-care of patients.
(3) Sufficient hospital accommodation at Angoda or elsewhere outside the city for incurable cases among the indigent classes.
(4) A marine sanatorium for treatment of surgical tuberculosis.
(5) Clearance of the slums and establishment of a garden city for the working classes.
(6) Introduction of hygiene and physiology as compulsory subjects in the curriculum of all schools.
(7) Provision by the State of a number of cottages at Bandarawela or Kankesanturai which could be let at reasonable rates for the middle classes and the appointment of a District Medical Officer with suitable training to advice upon treatment and régime to be followed. At present consumptive patients rush off to Bandarawela and other places noted for their salubrity under the idea that climate alone can do everything but do not follow a proper régime nor take sufficient precautions regarding disinfection of sputum, &c., with the result that these resorts run great risk of becoming infected with tuberculosis and of being avoided as dangerous places to go to. There is also the great difficulty at present of securing house accommodation at such places owing to the disinclination of landlords to let their houses to consumptive patients and those who are willing to let them demand such rents as are beyond the means of people of moderate means. Provision of small cottages in a selected site at moderate rents would confine tuberculosis patients to a particular area and would enable such people to go up with one or two members of their family to look after and keep house for them, and the Medical Officer could direct the proper treatment and the regime to be followed by each case.

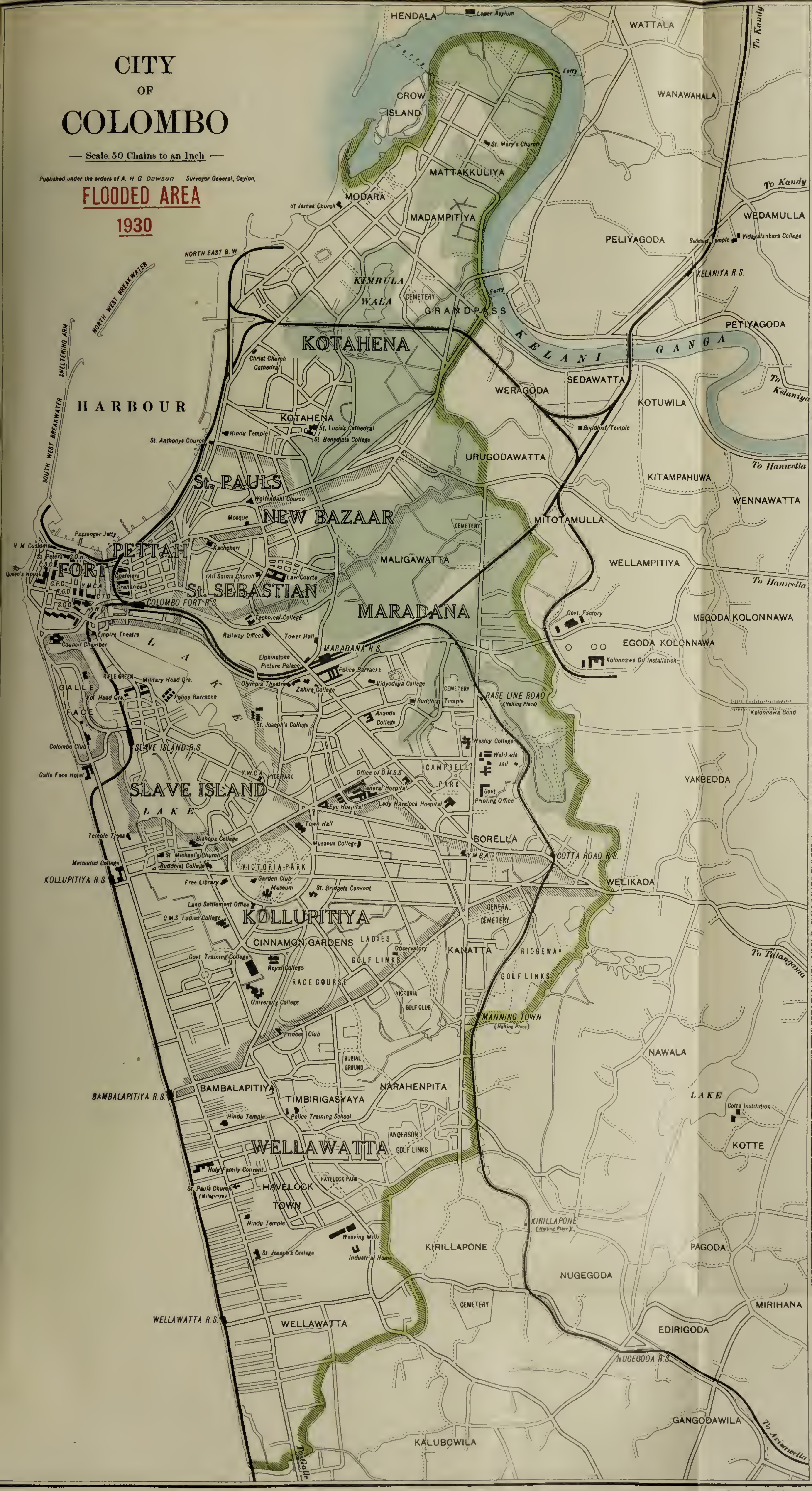
XV.—The Effect of the Floods on the Health of the City.

Colombo was affected by a flood of unprecedented magnitude in the month of May and about one-fifth of the city was inundated by the overflow of the Kelani river which forms the northern boundary of the Municipality (see Map No. 2). There was also a minor flood in October which caused but little damage. The direct and immediate result of the major flood was the submersion in varying degrees of *inter alia* the great majority of the dwelling houses and all the wells and latrines situated in the affected areas. The inhabitants perforce had to flee at very short notice from the dangers of drowning and of crumbling houses and to seek shelter in houses of relatives or friends, in public institutions, railway carriages, and temporary refugee camps provided by the Council. Exposure to the incessant rain, wetting due to attempts to salvage their household goods, unavoidable crowding together of refugees, bathing in the polluted flood waters, and the subsequent plague of flies, naturally led in the weeks following to an increased incidence of sickness and mortality. These possibilities were anticipated and strenuous efforts were made by the Health Department to warn the people against the threatened dangers and to clean up the affected areas, chlorinate wells, disinfect premises and lavatories, and to offer free inoculation against enteric fever. In spite of these efforts, which no doubt helped to minimize the danger materially, the effect of the floods on the health of the city was marked as will be seen in the following sections.

The wards affected by the floods were Mutwal, Kotahena, New Bazaar, Maradana North, and Dematagoda.

(*a*) *Enteric Fever.*

There were reported 846 cases, of which 6 were from the port, 467 from outside town limits, and 373 town cases, as against 301 in the previous year. Of the 373 town cases, 114 ended fatally, representing a case mortality of 30·6. Twenty-five of the town cases occurred in the prison. The setback in regard to this disease was mainly due to the floods. The very large number of outside cases, viz:, 467, as against 332 in the previous year, is further evidence of the injurious effect of the flood on the districts adjoining the city which in common with Colombo suffered badly.



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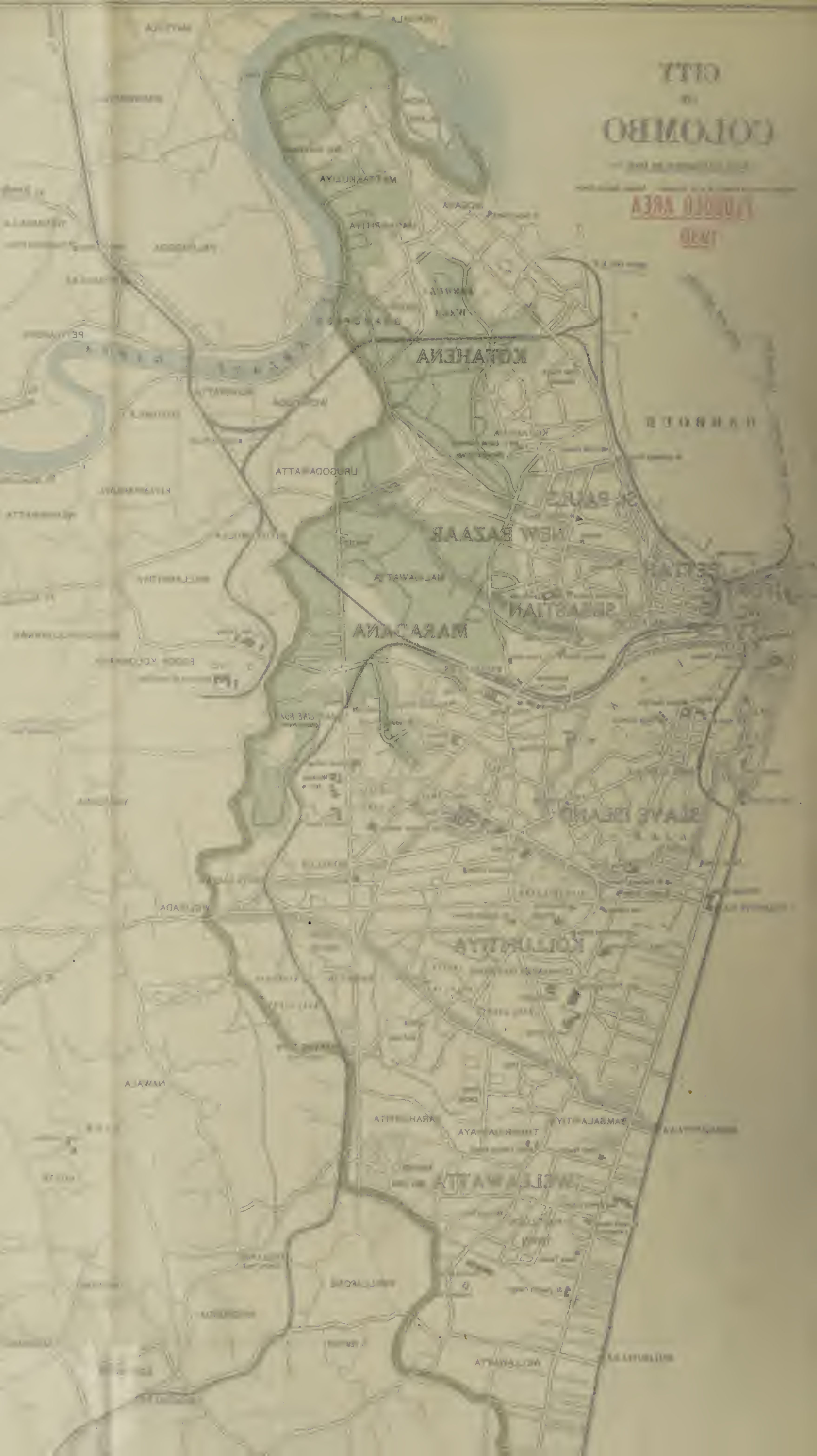


I.—BASELINE ROAD SHOWING FLOODED HOUSES AND INMATES MOVING OUT WITH THEIR HOUSEHOLD IMPEDIMENTA.

II.—MALIGAWATTA FLOODED AREA, SHOWING PEOPLE TAKING REFUGE ON THE RAILROAD TRACK.

The following statement shows that the five wards affected by the floods had the highest number of cases :—

Ward.	No. of Cases.	Ward.	No. of Cases.
Fort	1	Kollupitiya	11
Pettah	3	Cinnamon Gardens ...	8
San Sebastian... ...	7	Bambalapitiya ...	12
St. Paul's	10	Timbirigasyaya ...	7
Kotahena	26	Wellawatta	19
Mutwal	37	Prisons	25
New Bazaar	32	Vagrants and Untraced ...	49
Maradana North ...	50		
Dematagoda	42	Town ...	373
Maradana South ...	19		
Slave Island	15		

The next statement shows the number of cases and deaths by months. The major flood occurred in the early part of May and the three succeeding months of June, July, and August showed the highest number of cases and deaths (see graph in Diagram No. 2).

Month.	No. of Cases.	No. of Deaths.	Month.	No. of Cases.	No. of Deaths.
January ...	30 ...	8	September ...	30 ...	7
February ...	31 ...	8	October ...	19 ...	5
March ...	31 ...	7	November ...	18 ...	4
April ..	24 ...	10	December ...	21 ...	9
May ...	37 ...	10			
June ...	38 ...	12		373	114
July ...	48 ...	15			
August ...	46 ...	19			

As a result of efforts made to popularize protective inoculation a large number of people availed themselves of this valuable prophylactic agent. Ninety-eight inoculations were performed at the Municipal Laboratory and Free Dispensaries and approximately 609 by private medical practitioners making a total of about 707 inoculations. Compared with the population this figure represents a very small percentage, but it is confidently hoped that people will in time begin to lose their fear of inoculations, appreciate its great protective value, and take better advantage of it.

(36) *Enteric Fever Cases reported during the Year, 1930 (exclusive of Port and Outside Cases).*

Distribution by Race, Sex, and Age.

Race.	Sex.	0 to 5 Years.	5 Years to 10 Years.	10 Years to 15 Years.	15 Years to 20 Years.	20 Years to 25 Years.	25 Years to 30 Years.	30 Years to 35 Years.	35 Years to 40 Years.	40 Years to 50 Years.	50 Years to 60 Years.	60 Years and Over.	All Ages.	Total for each Race.	Number of Deaths.	Case Mortality per cent.
All Races ...	Males ...	5	24	28	51	37	34	20	10	9	2	1	221	373	114	30·6
	Females ...	3	22	22	23	28	19	14	5	10	5	1	152			
Europeans ...	Males ...	—	—	—	—	—	—	—	—	1	—	—	1	3	—	—
	Females ...	—	—	—	—	—	—	1	—	1	—	—	2			
Burghers ...	Males ...	—	2	2	3	3	3	2	—	—	—	—	15	29	12	41·4
	Females ...	—	—	1	2	3	2	5	—	1	—	—	14			
Sinhalese ...	Males ...	4	17	20	31	21	24	10	5	3	1	1	137	249	70	28·1
	Females ...	3	18	16	19	21	12	6	5	8	3	1	112			
Tamils ...	Males ...	1	3	2	5	5	1	4	3	2	—	—	26	38	14	36·8
	Females ...	—	2	4	1	—	3	1	—	—	1	—	12			
Moors ...	Males ...	—	1	2	4	3	1	—	—	—	1	—	12	19	7	36·8
	Females ...	—	2	—	—	2	1	1	—	—	1	—	7			
Malays ...	Males ...	—	1	1	2	—	—	—	—	—	—	—	4	6	2	33·3
	Females ...	—	—	1	1	—	—	—	—	—	—	—	2			
Others ...	Males ...	—	—	1	6	5	5	4	2	3	—	—	26	29	9	31·3
	Females ...	—	—	—	—	2	1	—	—	—	—	—	3			

(*b*) *Continued Fever.*

187 cases were reported, of which 50 were outside cases and 137 town cases, as against 132 in the previous year, with 65 deaths, the majority if not all of which must be regarded as due to unrecognized enteric fever.

Here again the effect of the flood is seen in the two following statements :—

Ward.	No. of Cases.	Ward.	No. of Cases.	Ward.	No. of Cases.
Fort ...	—	Maradana North ...	13	Timbirigasyaya ...	3
Pettah ...	1	Dematagoda ...	12	Wellawatta ...	2
San Sebastian ...	6	Maradana South ...	6	Prisons ...	1
St. Paul's ...	14	Slave Island ...	7	Vagrants and Untraced	17
Kotahena ...	19	Kollupitiya ...	4		
Mutwal ...	17	Cinnamon Gardens ...	—	Total ...	137
New Bazaar ...	15	Bambalapitiya ...	—		

Month.	No. of Cases.	No. of Deaths.
January	13	4
February	10	5
March	10	5
April	4	2
May	8	2
June	22	9
July	19	7
August	20	13
September	9	6
October	8	2
November	3	5
December	11	5
Total	137	65

(*c*) *Dysentery.*

There were reported 542 cases, of which 7 were from the Port, 124 from outside city limits, and 411 town cases, as against 435 in the previous year. Of the 411 town cases, 73 were reported as amœbic, 32 as bacillary, and the remainder were unspecified. Of these, 115 or 28·0 per cent. ended fatally.

Dysentery showed slight improvement over the previous year and but for the floods and the subsequent plague of flies would have shown greater improvement.

Ward.	No. of Cases.
Fort	1
Pettah	2
San Sebastian	6
St. Paul's	31
Kotahena	22
Mutwal	30
New Bazaar	24
Maradana North	35
Dematagoda	34
Maradana South	17
Slave Island	50
Kollupitiya	24
Cinnamon Gardens	6
Bambalapitiya	9
Timbirigasyaya	11
Wellawatta	17
Prisons	18
Untraced	74
Total	411

From the above statement it will be seen that three wards, namely, Slave Island, St. Paul's, and Kollupitiya which were not affected by the flood show a larger number of cases than some of the affected wards. In the course of investigations it was found that many of the cases particularly those from Slave Island Ward had not been bacteriologically confirmed and there was reason to believe they were more likely cases of enteritis rather than dysentery. Flies were bad nearly all over the town which perhaps accounts for the high incidence in wards other than those affected by the floods.

Month.	No. of Cases.	No. of Deaths.
January	43	11
February	22	12
March	10	5
April	10	6
May	17	2
June	71	12
July	118	26
August	33	8
September	38	10
October	19	12
November	18	4
December	12	7
Totol	411	115

The above statement shows that the largest number of cases occurred in the two months succeeding May with the highest number of deaths in July.

(*d*) *Diarrhœa and Enteritis.*

Not being notifiable the number of cases cannot be given.

The total number of deaths reported was 846, but exclusive of deaths of non-residents in hospitals the number was 696, as against 828 in the previous year.

The following statement shows the monthly deaths and it will be noted that the highest number occurred in the months of June, July, and August :—

Month.	No. of Deaths.
January	58
February	43
March	45
April	29
May	37
June	88
July	152
August	92
September	34
October	40
November	41
December	37
Total	696

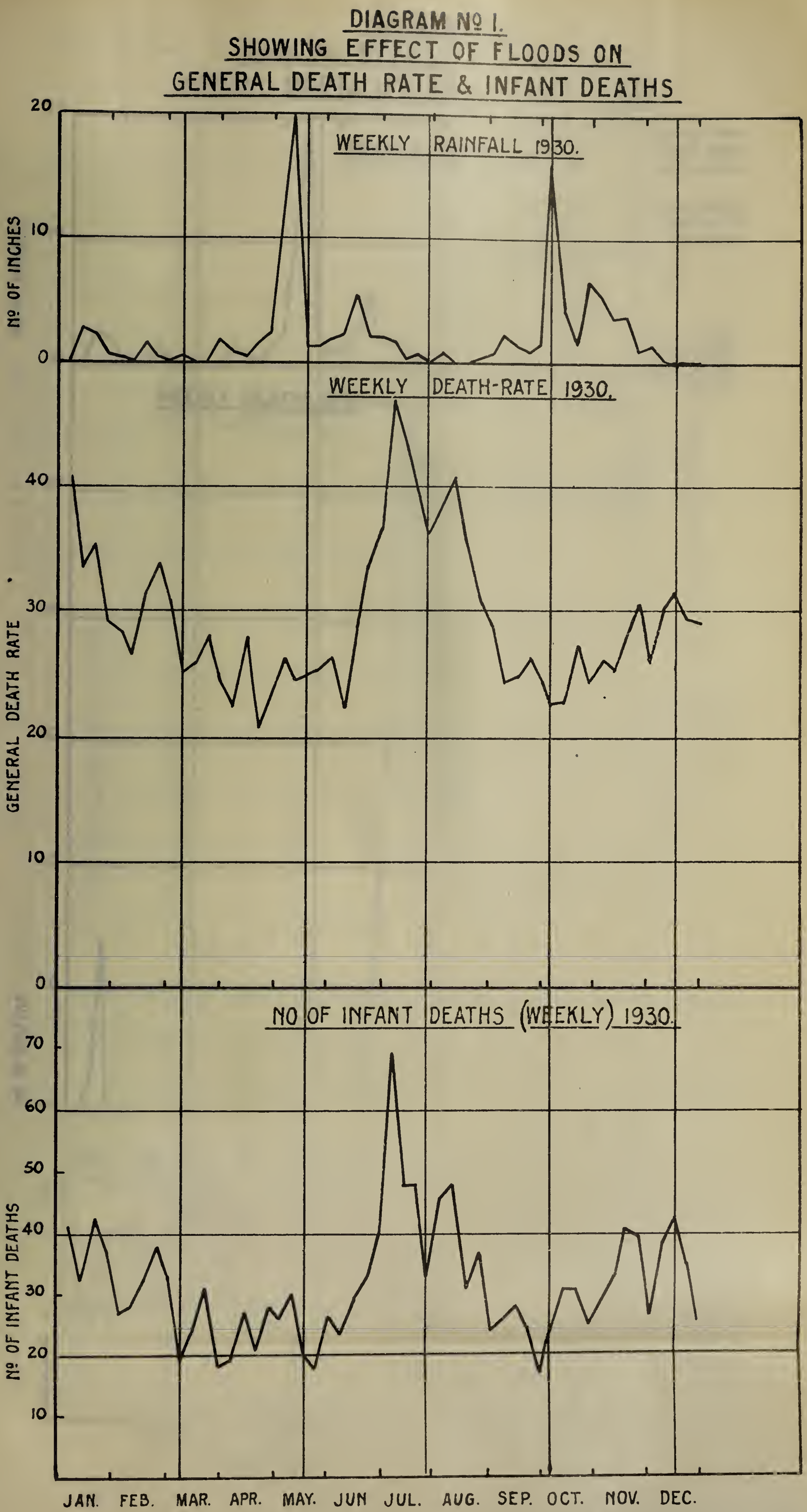
(*e*) *Pneumonia.*

There were 925 deaths but exclusive of deaths of non-residents the number was 723. The monthly distribution given below shows an increase after the major and minor floods in May and October, respectively (*vide* Diagram No. 3).

Month.	No. of Deaths.
January	61
February	42
March	42
April	35
May (major flood)	36
June	45
July	107
August	93
September	64
October (minor flood)	58
November	74
December	67
Total	723

III.—A CLOSE UP VIEW OF FLOOD REFUGEES WITH THEIR CATTLE AND BELONGINGS ON THE RAILROAD TRACK.

IV.—DAMAGE CAUSED TO HOUSES BY THE HEAVY RAINS.



REPRODUCED & PRINTED BY SURVEY DEPT CEYLON. 12 3 31

DIAGRAM No 1.
SHOWING EFFECT OF FLOODS ON
GENERAL DEATH RATE & INFANT DEATHS

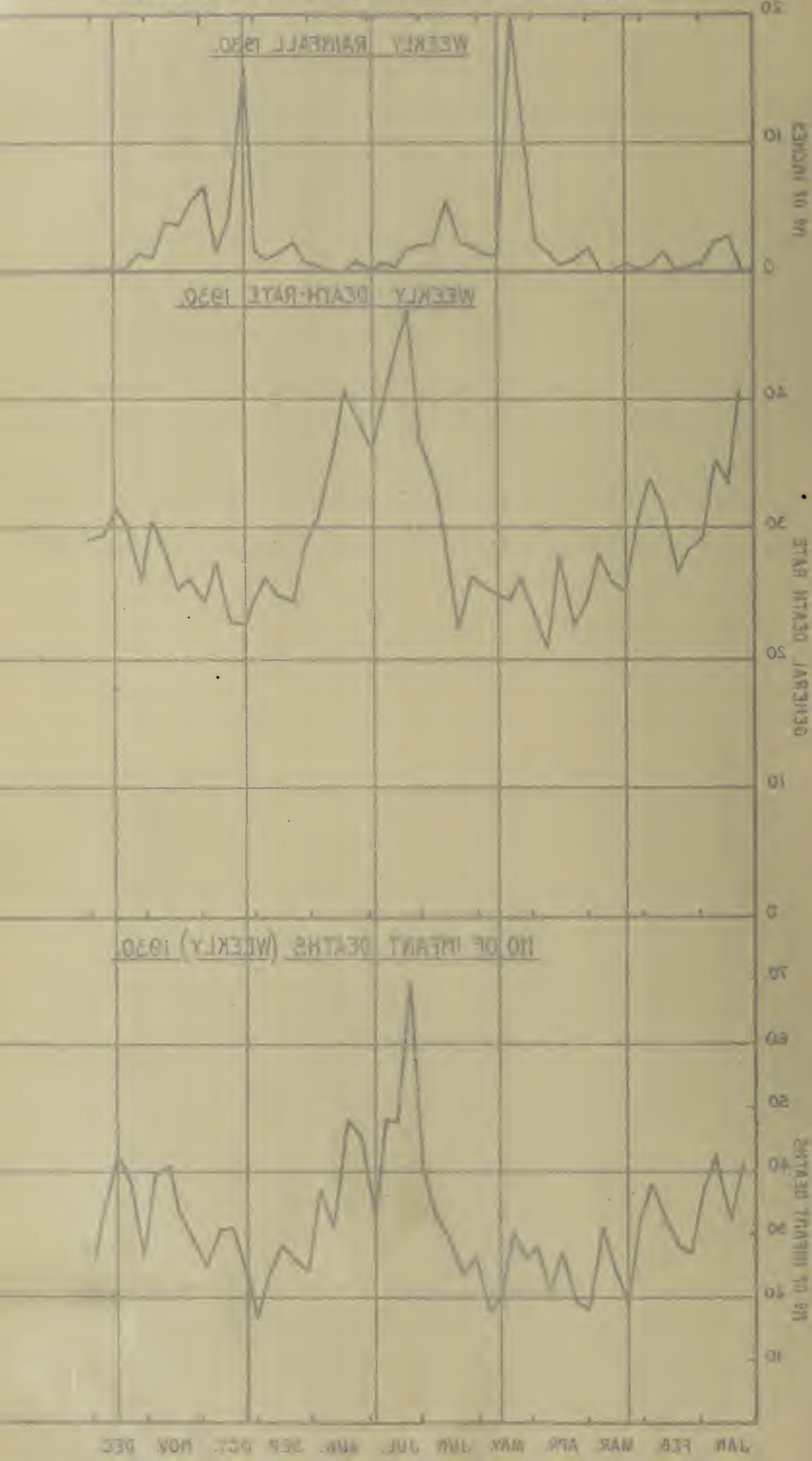
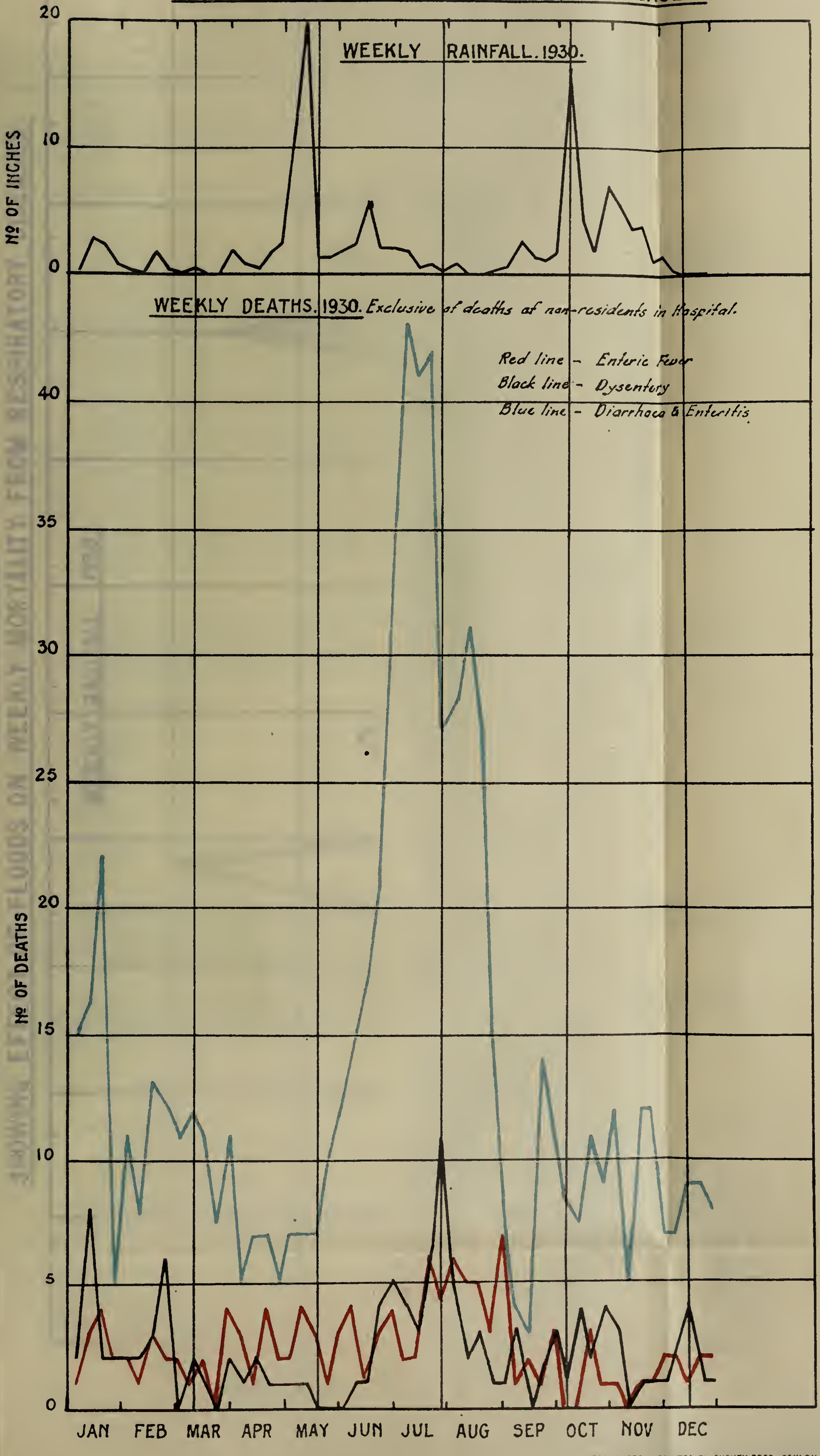


DIAGRAM No 2.
SHOWING EFFECT OF FLOODS ON
WEEKLY MORTALITY FROM BOWEL DISEASES



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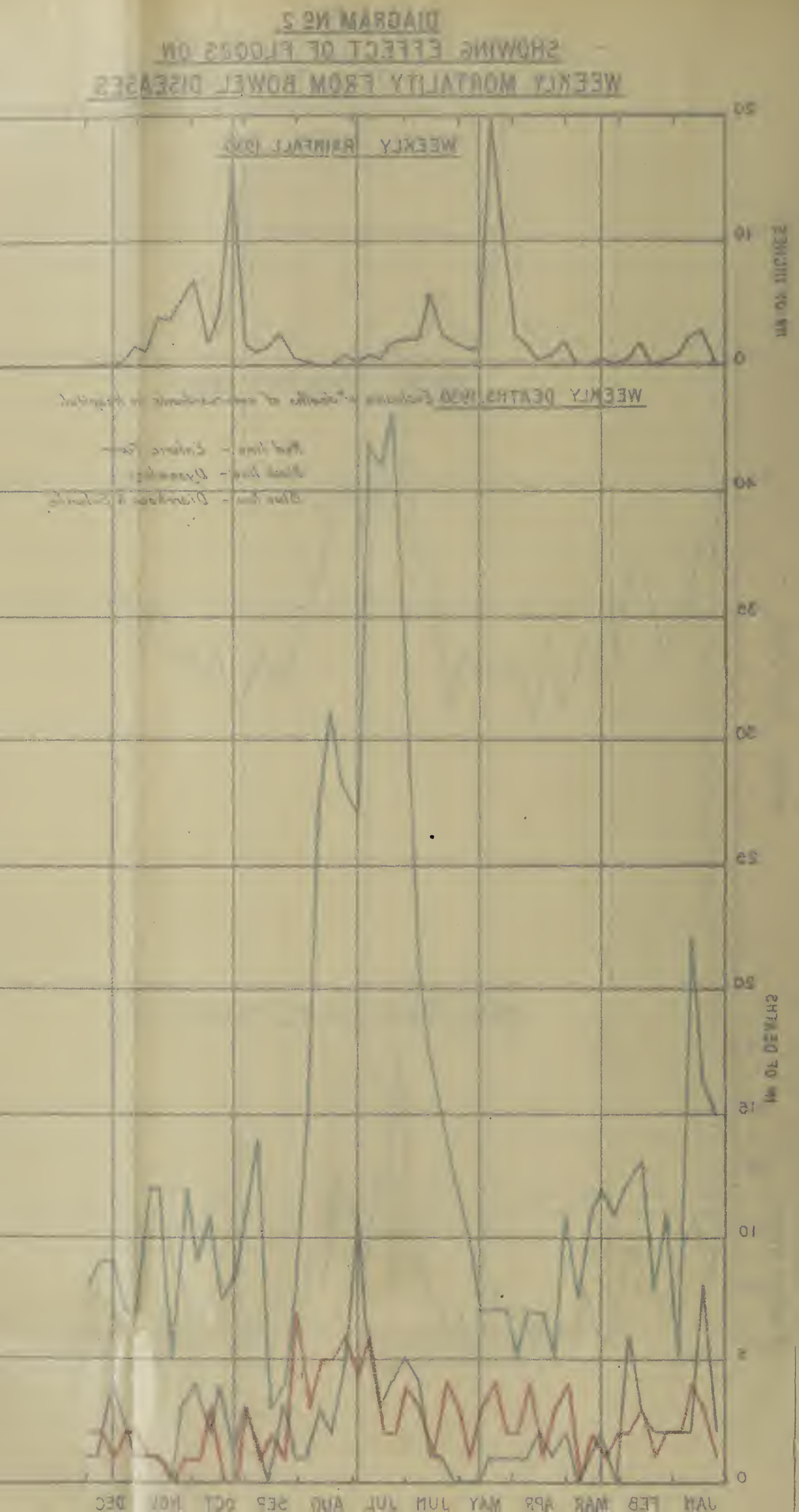
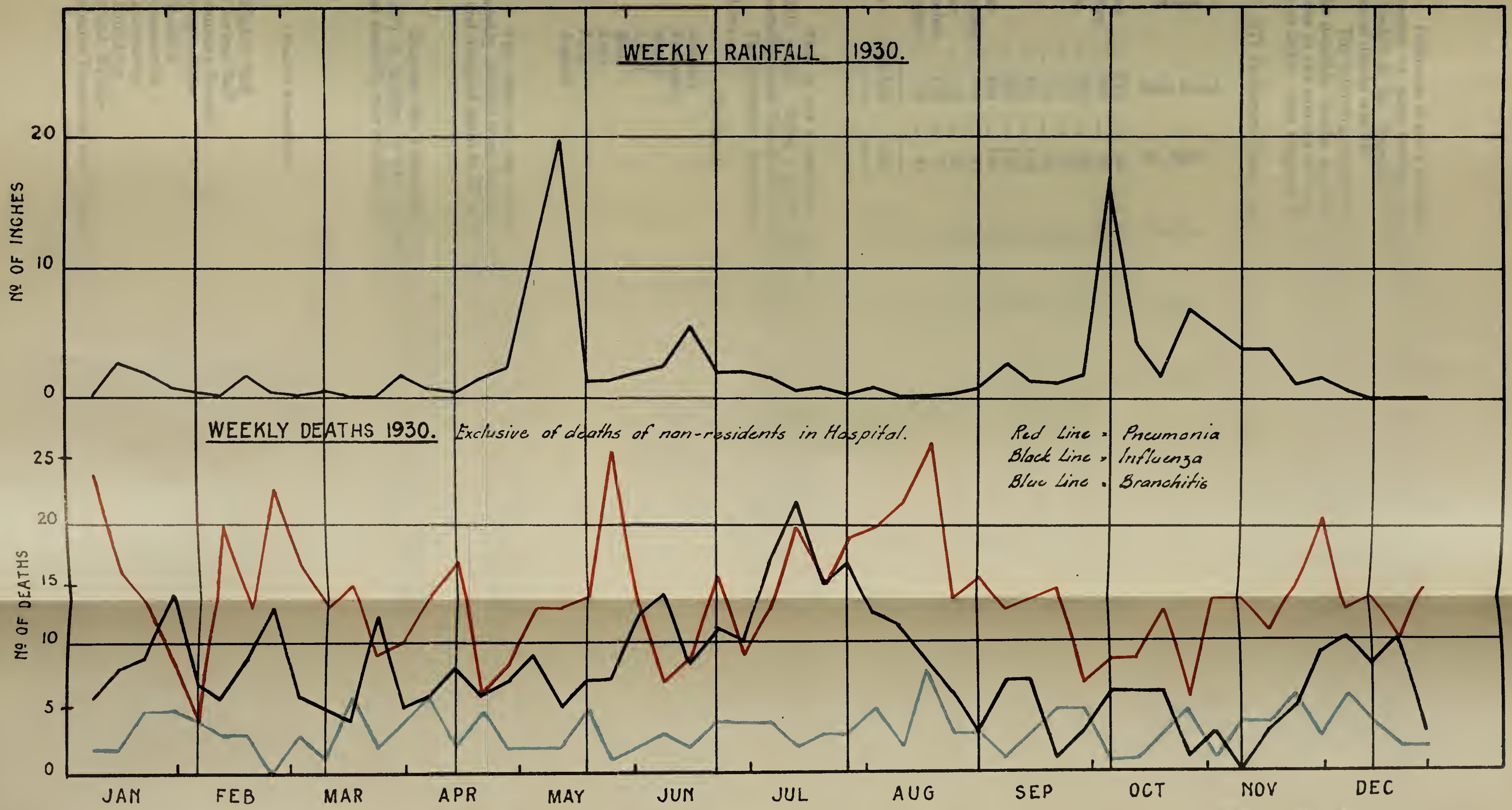


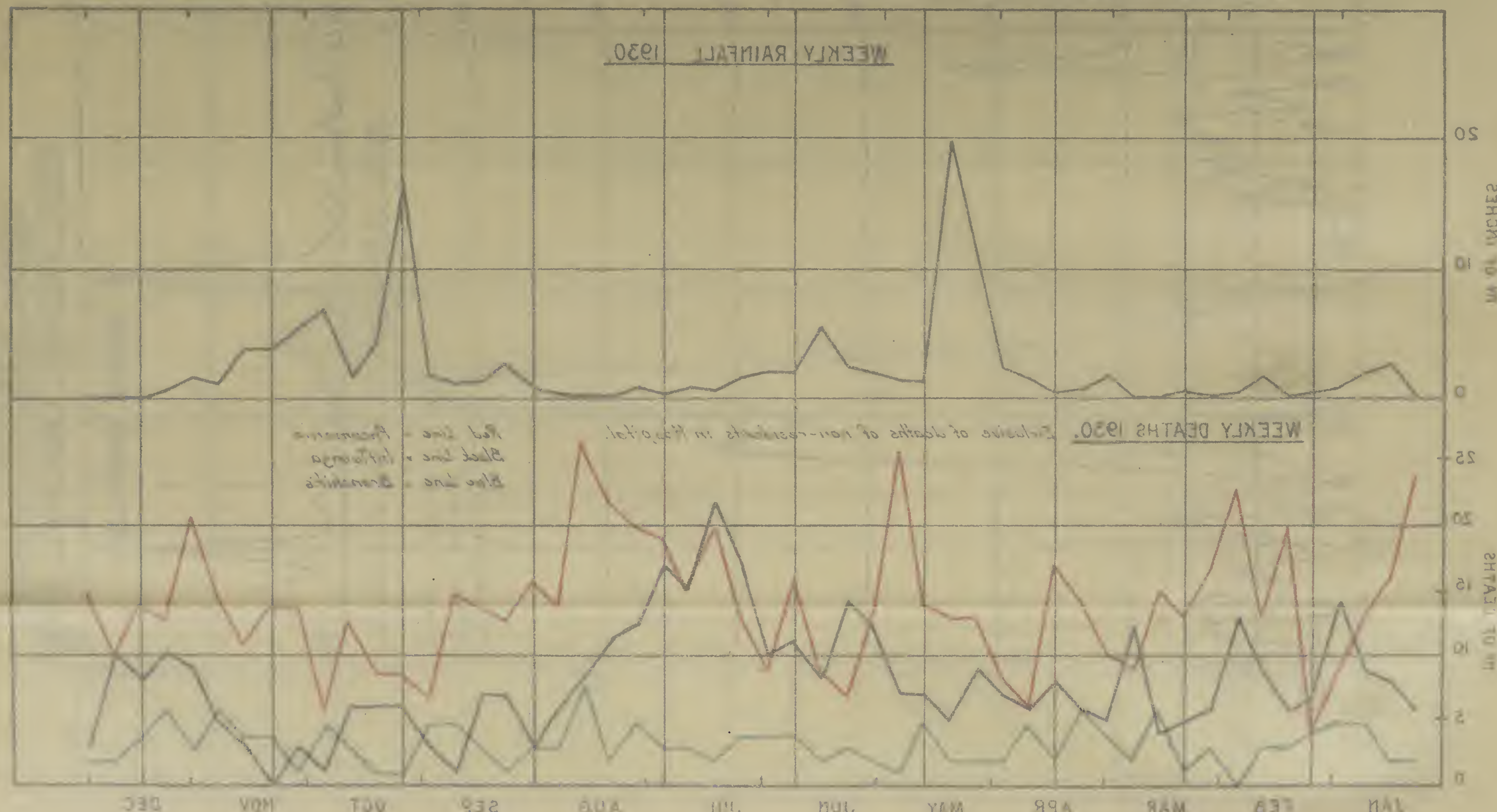
DIAGRAM No 2
SHOWING EFFECT OF FLOODS ON
WEEKLY MORTALITY FROM BOWEL DISEASES
WEEKLY RAINFALL 1930
WEEKLY DEATHS 1930
No OF INCHES
No OF DEATHS
JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC

DIAGRAM № 3.
SHOWING EFFECT OF FLOODS ON WEEKLY MORTALITY FROM RESPIRATORY DISEASES



<u>DIAGRAM Nº 3.</u>

<u>SHOWING EFFECT OF FLOODS ON WEEKLY MORTALITY FROM RESPIRATORY DISEASES</u>



(*f*) *Influenza.*

Influenza is not a notifiable disease. Its prevalence in the city can only be inferred from the number of cases seeking treatment at the various Municipal Free dispensaries. 7,199 cases were treated at the dispensaries and there were 418 deaths but exclusive of non-residents the number of deaths was 415.

The following statement shows the number of cases treated at the Municipal dispensaries and the monthly deaths exclusive of non-residents. It will be seen that the largest number of cases was in the months of June, July, and August and the highest number of deaths was in the month of July. (See Diagram No. 3.)

(37) *Influenza Cases reported from Municipal Dispensaries during each Month of the Year 1930.*

Month.	Slave Island.	St. Paul's.	Maradana.	Mutwal.	New Bazaar.	Wellawatta.	San Sebastian.	Total.	Monthly Deaths, exclusive of Deaths of Non-residents in Hospital.
January	179	40	124	84	54	16	169	666	42
February	109	23	118	82	32	10	118	492	36
March	105	29	90	64	42	18	156	504	29
April	89	51	68	54	10	8	124	404	28
May	85	52	125	64	26	9	40	401	33
June	174	105	97	122	51	6	151	706	48
July	295	158	229	122	68	24	397	1293	76
August	154	106	148	170	14	17	245	854	31
September	74	42	59	52	19	9	167	422	20
October	93	56	108	51	10	28	174	520	19
November	129	75	117	79	13	26	144	583	18
December	76	45	70	69	14	23	57	354	35
Total	1,562	782	1,353	1,013	353	194	1,942	7,199	415

(*g*) *Bronchitis.*

This is not a notifiable disease and therefore its prevalence during the year cannot be definitely stated. Being a milder disease than pneumonia and more amenable to simple treatment the mortality from this disease was not markedly increased as a result of the flood.

The monthly distribution of deaths exclusive of non-residents from this cause was as follows ;—

Month.	No. of Cases.	Month.	No. of Cases.
January	16	September	15
February	10	October	11
March	16	November	18
April	14	December	15
May	11		
June	14	Total	172
July	14		
August	18		

(*h*) *Infant Death-rate.*

The effect of the floods on the infant population is well shown in Diagram No. 1. The weekly average from January to May was 27 deaths, but from June to August the average rose to 39 and dropped again to 33 in the last quarter.

(*i*) *General Death-rate.*

Diagram No. 1 shows the effect of the floods on the general death-rate which declined from 33·1 in January to 24·9 in May and again shot up to 30·3 in June and 41·9 in July, the highest monthly rate recorded for the year.

XVI.—Expenditure—1930.

	Head of Expenditure.	Estimated Expenditure. Rs. c.	Actual Expenditure. Rs. c.	Savings. Rs. c.
1.	Higher Staff	58,440 0	58,440 0	—
2.	Clerical Staff	23,952 0	23,430 65	521 35
3.	Sanitary Branch	198,721 0	181,369 22	17,351 78
4.	Dispensaries	89,566 0	75,776 50	13,789 50
5.	Markets	46,168 0	43,278 18	2,889 82
6.	Cemeteries	27,103 0	25,166 10	1,936 90
7.	Laboratory	40,615 88	39,652 22	963 66
8.	Laundries	4,256 0	3,324 89	931 11
9.	Child Welfare	69,293 0	58,110 26	11,182 74
10.	Health Education and Propaganda Work..	2,500 0	2,407 7	92 93
	Total	560,614 88	510,955 9	49,659 79

XVII.—General Sanitation.

Statements, 38 and 39 give details of the work done during the year by the Ward Inspectors.

(38) *Ward Inspectors' Statement of Prosecutions and Convictions during 1930.*

Ordinance or By-law.	Offence.	No. of Prosecutions.	*No. of Convictions.
Section 1, sub-section (1), of Ordinance No. 15 of 1862 :	Filthy premises ...	566	530
Section 1, sub-section (1), of Ordinance No. 15 of 1862 :	Filthy dairy ...	21	19
Section 1, sub-section (1), of Ordinance No. 15 of 1862 :	Filthy laundry ...	1	2
Section 1, sub-section (4), of Ordinance No. 15 of 1862 :	Nuisance by cattle, swine, &c.	26	23
Section 1, sub-section (9), of Ordinance No. 15 of 1862 :	Selling unwholesome food.	2	2
Seetion 39 of Ordinance No. 1 of 1896 :	Unlicensed dairy	2	1
Section 53 of Ordinance No. 1 of 1896 :	Unregistered laundry	36	29
Regulation 89 made under section 4 of Ordinance No. 3 of 1897 :	Storing rice in unauthorized places	14	14
Section 38 of Ordinnce No. 6 of 1910 :	Failure to affix name board in dairy ...	1	1
Section 178 of Ordinance No. 6 of 1910 :	Failure to limewash	39	34
Section 180 of Ordinance No. 6 of 1910 :	Failure to fill swampy land ...	9	8
Section 184 of Ordinance No. 6 of 1910 :	Committing nuisance	14	11
Section 190 of Ordinance No. 6 of 1910 :	Failure to provide privy accommodation	11	10
Section 205 of Ordinance No. 6 of 1910 :	Failure to report infectious disease ...	2	2
Rule 29, chapter VIII., Municipal by-laws :	Digging pits and wells without permission	5	1
Rule 30, chapter VIII., Municipal by-laws :	Discharge of offensive liquid waste into private lands	1	1
Rule 4, chapter IX., Municipal by-laws :	Filthy bathing place ...	3	1
Rule 31, chapter IX., Municipal by-laws :	Failure to properly dispose of rubbish...	—	—
Rule 1, chapter XI., Municipal by-laws :	Unlicensed eating-house ...	117	92
Rule 7, chapter XI., Municipal by-laws :	Filthy eating-house ...	33	28
Rule 7, chapter XI., Municipal by-laws :	Filthy bakery	14	13
Rule 8, chapter XI., Municipal by-laws :	Unclean workmen in bakery ...	7	7
Rule 20, chapter XI., Municipal by-laws :	Using eating-house for another trade ...	1	1
Rule 3, chapter XIII., Municipal by-laws :	Disorderly conduct in public markets..	90	83
Rule 10, chapter XIII., Municipal by-laws :	Filthy private stall	6	6
Rule 22, chapter XIII., Municipal by-laws :	Selling goods in public market without ticket	—	1
Rule 28, chapter XIII., Municipal by-laws :	Throwing rubbish in market ...	13	13
Rule 29, chapter XIII., Municipal by-laws :	Filthy market stall	18	9
Rule 34, chapter XIII., Municipal by-laws :	Obstruction of passages in public markets	103	93
Rule 39, chapter XIII., Municipal by-laws :	Keeping cattle in excess of number allowed	20	21
Rule 2, chapter XIV., Municipal by-laws :	Exposing food to dust and flies ...	275	256
Rule 3, chapter XIV., Municipal by-laws :	Sale of adulterated milk ...	175	161
Rule 4, chapter XIV., Municipal by-laws :	Selling milk below standard ...	113	70
Rule 5, chapter XIV., Municipal by-laws :	Refusing sample of milk ...	4	3
Rule 7, chapter XIV., Municipal by-laws :	Unregistered milk vendor ...	114	101
Rule 5, chapter XVII., Municipal by-laws :	Burial without a certificate ...	1	—
	Total ...	1,857	1,648

XVIII.—Food Inspection.

Statement 40 (*a*) shows the work done by the whole-time Food Inspector and Statement 40 (*b*) the work done by Ward Inspectors in respect of destruction of foodstuffs found unfit for human consumption. Much of the fish sold in the Colombo markets come from outstations packed in ice and is liable to rapid deterioration in this climate, and complaints from the public regarding sale of bad fish are not infrequently made. Owing to the activity of the Food Inspector the quantity of bad fish sold both in the Municipal and private markets has decreased considerably.

A great deal of adulterated and very inferior grade teas are sold in the markets. Certain samples showed that exhausted tea leaves collected from eating-houses and tea shops had been dried, treated with bicarbonate of soda to produce the natural black colour, and mixed with a small quantity of good tea. Many other articles of food are subject to adulteration but in the absence of a pure Food and Drugs Act this Department is powerless to act.

Milk Supply.—A total number of 1,261 samples were taken during the year, 111 samples by the Food Inspector and 1,150 by the Ward Inspectors. Of these, 635 or 50·5 per cent. were found adulterated ; 411 samples with 1—10 per cent. added water, and 221 samples with above 10 per cent. added water. *Vide* Statement below.

The highest percentage of adulteration which is also the highest recorded so far was 81 per cent. A second sample taken a few weeks later from the same dairy showed adulteration of 66 per cent. The maximum penalty, namely, Rs. 50, now imposable under the present law, hardly acts as a deterrent, and a more severe penalty or temporary suspension of licence or cancellation of licence is called for.

The samples taken from unregistered vendors showed, as one would expect, the highest percentage of samples adulterated, namely, 74·3 per cent. ; next came the extra-urban dairies with 53·8 per cent., and third the town dairies with 44·7 per cent.

* Includes convictions obtained on prosecutions instituted during the previous year.

(39) *Work done by the Sanitary Staff during the Year 1930.*

Nature of Work.	Fort.	Pettah.	San Sebastian.	St. Paul's.	Kotahena.	Mutwal.	New Bazaar.	Maradana North.	Maradana South.	Dematagoda.	Slave Island.	Kollupitiya.	Cinnamon Gardens.	Bambalapitiya.	Timbirigasyaya.	Wellawatta.	Total.
1. Number of inspections	5,621	5,531	6,110	6,807	5,226	5,929	6,600	7,059	7,400	8,038	6,692	4,531	5,962	5,461	5,728	5,932	98,627
2. Number of premises where sanitary defects were found :— (*a*) Non-structural	117	99	182	240	101	150	202	342	139	147	181	248	90	155	121	195	2,709
3. Number of premises where sanitary defects were found :— (*b*) Structural	40	40	51	38	61	27	80	69	44	124	48	39	19	50	40	75	845
4. Number of premises where non-structural defects were rectified...	59	76	150	157	97	102	137	218	118	135	161	91	65	115	127	96	1,904
5. Number of premises where minor structural defects were rectified	17	46	21	23	52	18	49	53	28	109	44	13	6	45	30	36	590
6. Number of buildings, other than dwellings, structurally improved	21	25	2	8	—	—	31	—	—	—	—	12	4	18	3	—	124
7. Number of insanitary premises scavenged by Public Health Department Cleansing Gang	—	14	42	167	289	1,690	376	2,715	234	2,120	283	68	19	22	32	30	8,101
8. Number of dwellings disinfected	11	29	66	140	278	178	170	331	146	183	220	113	65	37	46	89	2,102
9. Number of dwellings limewashed	21	166	712	600	356	97	309	615	163	297	580	205	87	95	86	122	4,511
10. Number of wells filled up	—	—	—	—	8	—	1	6	—	1	—	1	4	—	1	—	22
11. Number of cesspits filled up	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
12. Number of notices served under section 1, sub-section (1), of Ordinance No. 15 of 1882. (Filthy premises) ...	9	19	75	50	84	25	113	268	107	125	46	100	23	64	32	67	1,197
13. Number of notices served under section 190 of Ordinance No. 6 of 1910. (Privy accommodation)	—	—	2	—	1	3	6	7	1	20	4	2	2	2	10	9	69
14. Number of notices served under section 180 of Ordinance No. 6 of 1910. (Filling up stagnant pools, &c.)	—	—	—	—	7	—	—	3	—	1	—	1	2	—	—	10	24
15 Number of notices served under section 178 of Ordinance No. 6 of 1910 (Cleansing and limewashing)	7	46	57	74	30	—	21	88	27	30	79	27	4	15	4	2	521
16. Number of notices served under by-law 8 (1), chapter 22, Plague Regulations. (Improvements to buildings unfit for human habitation)	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
17. Number of notices served under section 38, Part I., of Plague Regulations. (Filling up wells)	—	—	—	—	—	—	1	—	—	1	—	1	—	—	1	—	4
18. Number of milk samples taken under rule 5, chapter 14, Municipal by-laws	73	72	72	72	74	72	72	68	72	72	72	72	72	72	72	72	1,151
19 Number of prosecutions	45	107	152	86	164	69	108	219	167	152	160	130	75	54	70	180	1,938
20. Number of convictions	37	80	137	80	149	51	100	183	123	127	142	104	58	45	60	130	1,616
21. Number of cases acquitted, withdrawn, or otherwise dealt with...	3	7	8	1	26	3	4	8	17	15	12	7	1	8	8	19	147
22. Number of cases pending at end of year	5	4	9	1	12	—	4	17	9	12	6	8	5	6	6	5	109
	Rs.	Rs.	Rs.	Rs.	Rs.	Rs.	Rs.	Rs.	Rs.	Rs.	Rs.	Rs.	Rs.	Rs.	Rs.	Rs.	Rs.
23. Amount of fines	811·50	1,255·50	1,399	973·50	1,496	798	983·50	1,853	1,154·50	1,715·50	1,422 50	1,109	816·50	443	594·50	847	17,672·50

The milk supply of Colombo is still inadequate and unsatisfactory. The quality of the milk has been gradually getting worse since 1925 as the following table shows :—

Year.		Total Number of Samples examined.		Number adulterated.		Percentage.
1925	...	1,102	...	370	...	33·6
1226	...	1,163	...	408	...	35·17
1927	...	1,158	...	423	...	36·5
1928	...	1,237	...	486	...	39·3
1929	...	1,271	...	547	...	43·0
1930	...	1,261	...	635	...	50·5

The quantity of good milk available is small and of too high a price for the masses. It is encouraging to find that a village Co-operative Milk Society has been formed at Bomiriya with the object of supplying the town with cheaper milk of good quality and this society has already started sending in milk by motor van and are contemplating opening small supply depôts at one or two of the Municipal markets. This is a step in the right direction and I hope the public will patronize them and so encourage the formation of other societies.

A census taken last year showed that approximately 2,000 bottles of milk are brought into Colombo daily from the surrounding villages chiefly by itinerant vendors. This shows that the villages can and do produce milk, but owing to lack of co-operation and co-ordination the work is not done on proper business lines. If Co-operative Milk Societies can be formed in these villages a plentiful and cheap supply of milk can be ensured for Colombo.

(40) *Foodstuffs condemned during 1930.*

(*a*) By the Food Inspector.

In the Municipal Markets.

Fish	...	...	...	498¼ lb.
Meat	...	...	...	444¾ lb.
Vegetables and fruit		...	...	449½ lb.

In Private Markets in the Town.

Fish	...	...	...	137½	lb.
Stale curries and other meat and fish preparations				77	pots and dishes.
Rice	...	...	...	8	bushels.
Dhall	...	...	...	2	bushels.
Meat	...	...	...	61	lb.
Boiled eggs	...	...	...	5	
Stale soup	...	...	...	5	pots.
Vegetable and fish cutlets		...	...	13	plates.
Potatoes	...	...	...	80	lb.
Tinned food	...	...	...	475	tins.
Sweetmeats and cakes		...	...	51	trays and plates.
Stale rice	...	...	...	18	pots.
Fruit and vegetables		...	...	100	pots.
Lozenges	...	...	...	40	lb.
Rice-flour rotties..		...	...	33	
Dry fish	...	...	...	15	lb.

Samples of Food and Drink taken to City Analyst and City Microbiologist.

Milk ...	...	...	...	133
Flour ...	...	...	...	2
Aerated water	...	...	...	14
Arrack ...	...	...	...	10
Tinned food	...	...	...	103
Sweetmeats, cooked food, and pastry		...	...	44
Vinegar ...	...	...	...	5
Tea ...	...	...	...	10
Ghee ...	...	...	...	1
Lozenges (locally manufactured)		...	...	1
			Total ...	323

Prosecutions

Unregistered milk vendor	...	...	33
Adulteration of milk ...	...	...	62
Putrid meat and fish ...	...	...	22
Deficiency in fat ...	...	...	40
Food exposure ...	...	...	103
Refusing sample of milk for analysis	...	...	1
Unlicensed fish vendor ...	...	...	1
		Total ...	262

(*b*) By the Ward Inspectors.

(1) *At Chalmers Granaries.*

Rice	264 bushels and 7 measures.

(2) *In the Public Markets.*

Fish	12 lb.
Dhall	80 bags.

(3) *At Customs.*

Potatoes	20 cwt.

(4) *In Private Markets in the rest of the Town.*

Rice	48¼ bushels.
Potatoes	10 bags, 2,638 lb.
Meat	24½ lb.
Onions	3 bags, 392 lb.
Flour	8 lb.
Horse radish cream	4 bottles.
Smoked salmon	2 bottles.
Sauce	7 bottles.
Pickle	4 bottles.
Marsh mellows	10 tins.
Glaxo	1 tin.
Grape syrup	35 tins.
Brussels sprouts	40 tins.
Artichokes	20 tins.
Syrup	1 tin.
Pork	19 lb.

(41) *Milk Sampling during the Year 1930.*

Statement showing the Number of Samples adulterated with Water up to 10 Per Cent. and above 10 Per Cent.

		By Ward Inspectors.					By Food Inspector.						
		1 to 10 Per Cent. Water.		Above 10 Per Cent. Water.			1 to 10 Per Cent. Water.		Above 10 Per Cent. Water.			All Adulterations.	
Source of Samples.	Number of Samples taken.	Number of Samples adulterated	Percentage of Samples adulterated	Number of Samples adulterated	Percentage of Samples adulterated	Number of Samples taken.	Number of Samples adulterated	Percentage of Samples adulterated	Number of Samples adulterated	Percentage of Samples adulterated	Total Number of Samples taken.	Number of Samples adulterated	Percentage of Samples adulterated
Town dairies	793	257	32·4	81	10·2	67	19	28·4	28	41·8	860	385	44·7
Unregistered vendors ...	117	30	25·6	55	47·0	35	4	11·4	24	68·6	152	113	74·3
Dairies outside Colombo ...	240	97	40·4	30	12·5	9	4	44·4	3	33·3	249	134	53·8
Total ...	1,150	384	33·4	166	14·4	111	27	24·3	55	49·5	1,261	632	50·1

(42) *Food Trades Inspections during the Year 1930—Number of Inspections made.*

Ward.	Bakeries.	Dairies.	Eating-houses.	Public Markets.
Fort	42	—*	1,191	—†
Pettah	195	—*	858	141
San Sebastian	70	—*	719	278
St. Paul's	219	492	369	105
Kotahena	161	191	139	63
Mutwal	118	162	75	182
New Bazaar	190	312	484	—†
Maradana North	123	330	515	—†
Maradana South	144	—*	877	117
Dematagoda	148	158	570	—†
Slave Island	296	112	732	92
Kollupitiya	152	330	356	75
Cinnamon Gardens	50	409	492	275
Bambalapitiya	116	103	162	148
Timbirigasyaya	60	194	270	—†
Wellawatta	99	149	314	94
Total ...	2,183	2,942	8,123	1,570

*No dairies in these wards.

† No public markets in these wards.

XIX.—Markets.

No new Municipal markets were erected last year. The sanctioned market for the Dematagoda-Kolonnawa area is under construction and will be opened to the public about the middle of the current year. This will bring the number of Municipal markets up to 14.

XX.—Dairies.

Number at beginning of the year	...	...	56
New dairies registered	...	...	3
Total at end of year ...	...	...	59

Out of the 59 dairies 41 were involved in prosecutions for adulteration and 38 for other offences.

(43) *Number of Convictions, 1930.*

Offence.		No. of Convictions, 1929.		No. of Convictions, 1930.
Selling adultreated milk	... ...	101	...	113
Selling milk deficient in fat ...	...	6	...	59
Keeping cattle in excess of number licensed		19	...	21
Keeping dairy filthy	... ...	46	...	19
Total	...	172	...	212

XXI.—Bakeries.

Number at beginning of year	...	...	54
Number discontinued ...	...	...	2
Number at end of year ...	...	...	52

Out of the 52 bakeries 16 were involved in prosecutions.

Number of Convictions, 1930.

Offence.		No. of Convictions, 1929.		No. of Convictions, 1930.
Unclean bakery	...	31	...	13
Unclean workmen	...	14	...	7
Total	...	45	...	20

The bakery by-laws which were proclaimed in November, 1929, were further amended and modified and passed into law in August, 1930. These by-laws are now being enforced in full in respect of all new bakeries and in a modified form in respect of the old bakeries.

XXII.—Eating-houses and Tea Shops.

As a concession to the strong opposition raised by those affected the by-laws passed in October, 1928, were modified and amended and passed into law in November, 1929, but even these modified by-laws were received with such antagonism that they had to be still further relaxed.

From the public health point of view the regrettable aspect of it is that all the tea shops which deal in comestibles other than cooked rice have been exempted from the operation of these by-laws. As I have frequently pointed out these tea shops, for all practical purposes, are eating-houses and unless they are brought under control and supervision the wholesomeness and cleanliness of the public food supply cannot be ensured.

The new by-laws were proclaimed in August, 1930, but as time was allowed for compliance with its terms the majority of the eating-houses escaped registration last year.

XXIII.—Laundries.

(a) *Public Laundries.*

No new laundries were constructed during the year.

The preliminary work of providing housing in connection with the sanctioned laundry for New Bazaar is going on and the laundry itself will probably be ready by the end of 1931.

(b) *Private Laundries.*

Number at beginning of year	...	...	...	284
Number discontinued	...	...	...	8
Number of new registrations	..	...	...	22
Number at end of year	...	...	...	298

XXIV.—Lavatories.

(a) *Public Lavatories.*

One new public lavatory was constructed and opened to the public at Darley road, bringing the total number of public lavatories up to 69.

The sites for three new ones in New Bazaar Ward are under consideration. The lavatory at Galle Face has not materialized yet owing to the difficulty of finding a site acceptable both to the Municipality and the Colonial Military authorities in whom is vested the Galle Face esplanade.

(b) *Private Lavatories.*

Owing to the present financial situation of the country enforcement of drainage connections has been temporarily stopped and all work in this connection is now entirely voluntary. During the year 902 pail latrines were abolished and 2,275 new water closets installed. The total number of premises drained at end of 1930 was 9,169, as against 7,772 at the end of 1929.

XXV.—Mosquito Prevention.

The work done in this connection is shown in statement below :—

(44) *Anti-Mosquito Work, 1930.*

Complaints from Householders.

Number of complaints	278
Number of premises visited	1,702
Number of potential breeding places found	23,462
Number of actual breeding places found	4,415

General Inspection Work.

Number of premises visited	3,836
Number of tenements visited	791
Number of potential breeding places found	54,130
Number of actual breeding places found	5,275

The total number of complaints was 278, as against 552 in the previous year.

XXVI.—Disinfecting and Cleansing.

Work done at the Steam Disinfecting Station.

Number of van loads of clothing, &c., disinfected	189
Number of articles included in above	5,669

Work done by the Municipal Cleansing Gang.

In addition to the regular and routine work of the Cleansing Gang in cleaning up various premises situated chiefly in the poorer district of the town where cases of infectious disease, particularly enteric, had occurred or which were found to be in a neglected state owing to ownership of property being in dispute and sub-judice, whole areas situated in the congested parts of the town were cleaned up on certain selected days by drafting all the Anti-Mosquito Gang coolies and Anti-Plague coolies to help the regular Cleansing Gang coolies. By the employment of a large gang of coolies amounting to about 80 men, with a staff of about 12 overseers, it was possible to clean up large areas and remove a great deal of accumulated filth. Not only were the compounds weeded and cleaned up but all the lavatories and drains were flushed out with disinfectants and the inmates of the houses were persuaded to put their things out and clean out their homes with the help of the Municipal coolies. In this manner large accumulations of useless rubbish and dirt were got rid of.

The statement below shows the work done by the massed gangs :—

(45) *Special Cleansing done in 1930.*

	No. of Premises scavenged.	No. of Latrines disinfected.	No. of Tenements cleaned out.	No. of Gardens cleaned out.	No. of Cartloads of Rubbish removed.
On February 8, 1930, Mutwal street area ...	23	45	127	—	16½
On March 8, 1930, Blomendahl road area ...	59	93	—	—	30
On May 3, 1930, Dematagoda area ...	81	144	—	—	22½
On June 12, 1930, Urugodawatta road area ...	32	14	—	—	12
On August 23, 1930, Madampitiya road area ...	52	123	—	—	5½
On August 30, 1930, Kochchikadde Slum area ...	—	88	—	58	33
On September 6, 1930, Alutmawata road area ...	—	—	161	29	28
On December 6, 1930, St. Joseph's street area ...	52	16	—	13	32
On December 13, 1930, Kolonnawa road area ...	107	36	—	25	50

XXVII.—Housing.

The work in connection with the Kochchikadde Slum Improvement Scheme was begun during the year and the first block of five units was completed in December, 1930, further preliminary work in connection with the other blocks is in progress.

(46) *List of Premises improved or demolished during 1930—By Wards.*

San Sebastian.

No. 54, San Sebastian street.
No. 21-22, Muhandiram's lane.
No. 17, Dias place.
No. 14-15, Dias place.

St. Paul's.

No. 12-15, Mosque lane.
No. 16, Mosque lane.
No. 49. Wolfendahl street.

Kotahena.

No. 8, Skinner's road north.

New Bazaar.

No. 68, Messenger street.
No. 99, Messenger street.
No. 56, Grandpass road.
No. 130-131, Grandpass road.
No. 34-35, Silversmith street.
No. 59-60, Silversmith street.
No. 25-27, Armour street.
No. 124-125 Layard's broadway.
No. 26, Grandpass road.
No. 52, Grandpass road.
No. 25, Messenger street.
No. 8-15, Silversmith lane.

Maradana North.

No. 1-9, Kolonnawa lane.
No. 11, Kolonnawa lane.
No. 21, Kolonnawa lane.
No. 31, Kolonnawa lane,
No. 61, Kolonnawa lane.
No. 47, Drieberg's lane.
No. 346 Dematagoda road.
No. 29-31, Piachaud's lane.
No. 50, Skinner's road south.
No. 43-47, Piachaud's lane.
No. 65 5/7, Panchikawatta raod.

Maradana.

No. 84a Dean's road.
No. 1, Tichborne road.
No. 36, Forbes road.
No. 143, Darley road.
No. 26, Forbes road.
No. 97-99, Dean's road.
No. 22, Forbes road.
No. 58-64, Forbes road.
No. 70, Forbes road.

Dematagoda.

No. 144-146, Dematagoda rood.
No. 17-19, Reservoir road.
No. 45, Ketawalamulla lane.
No. 110, Dematagoda road.
No. 196, Dematagoda road.

Slave Island.

No. 14, Lake road.
No. 17-29, Kew lane.
No. 34-44, Wekanda.
No. 30-36, Vauxhall Street.
No. 1, Leechman lane.

Wellawatta.

No. 8, Frederica road.

(47) *Statement of Work done by the Inspector of Insanitary Buildings during the Year 1930.*

1.	Number of plans called for from Municipal Engineer... ...	47
2.	Number of plans received	66
3.	Number of applications for "closing order"	34
4.	Number of "closing orders" issued	39
5.	Number of applications for "closing order" struck off ...	2
6.	Number of applications for "closing order" pending ...	3
7.	Number of prosecutions for allowing premises to be occupied after "closing order"	16
8.	Number of closing notices affixed on buildings	489
9.	Number of premises vacated after "closing order"	8
10.	Number of tenements vacated under (9) above	170
11.	Number of persons dishoused	326
12.	Number of premises improved	51
(*a*)	Number of tenements in (12)	1,299
(*b*)	Number of rooms demolished in (12)	458
(*c*)	Number of persons dishoused in (12)	714
(*d*)	Number of new doors provided in (12)	263
(*e*)	Number of new windows provided in (12)	629
(*f*)	Number of doors enlarged in (12)	594
(*g*)	Number of windows enlarged in (12)	288
(*h*)	Number of rooms cemented in (12)	1,790
(*i*)	Number of masonry partitions removed in (12) ...	169
(*j*)	Number of plank partitions removed in (12) ...	19
(*k*)	Number of gunny partitions removed in (12) ...	—
(*l*)	Number of rooms in which masonry walls have been replaced by trellis	599
(*m*)	Spaced unroofed in (12) in square feet	304
(*n*)	Length of roof raised (in feet)	5,251
13.	Amount of fines	Rs. 260/-

XXVIII.—Municipal Free Dispensaries.

The dispensaries continue to be very useful and popular.

The new building for the Slave Island dispensary is nearing completion and will be ready for occupation in a couple of months. The Medical Officer who has been working for many years under very unfavourable conditions will soon have a more commodious and modern type of building to work in. Another dispensary which is working under difficulties is the Mutwal one and the next Municipal dispensary building should be put up in this ward.

(48) *Work done at the Municipal Free Dispensaries during 1930.*

	Slave Island Dispensary.	St. Paul's Dispensary.	Maradana Dispensary.	Modera Dispensary.	New Bzaar Dispensary.	Wellawatta Dispensary.	San Sebastian Dispensary.	Total.
Number of patients treated ...	19,044	10,666	16,436	13,811	9,599	8,289	8,955	86,800
Number of visits by patients ...	37,802	18,374	28,739	22,692	17,930	18,503	18,303	162,343
Daily average attendance ...	122	59	93	73	58	60	60	—
Number of outdoor visits paid by the Medical Officers ...	69	31	127	294	21	38	6	—
Number of Municipal employees treated	551	19	110	26	243	270	120	1,339
Number of persons inoculated against typhoid... ...	8	4	24	2	29	8	4	79

XXIX.—Maternity and Child Welfare.

Owing to the difficulty of getting a suitable female Medical Officer, Dr. C. G. Peiris, a medical practitioner in private practice, was temporarily appointed to the post of Medical Officer in charge of Maternity and Child Welfare on July 10, 1930. In pursuance of the resolution of Council dated July 10, 1929, the duties of controlling and supervising the work of midwives as required by regulation 2 of section 58 of Ordinance No. 26 of 1927 were also assigned to him.

I am very pleased to be able to report that Dr. Peiris has proved eminently satisfactory and under his guidance this branch of our work which had a somewhat chequered existence owing to frequent change of Medical Officers is now in a settled state and is going on very smoothly and successfully.

The clinics are very well patronized and the attendance of Muslim women is very encouraging.

The Birmingham method of visiting and card-keeping has also been introduced in a modified form to suit local conditions and under Miss Wambeek's direct supervision the work is progressing in a satisfactory manner.

The staff of the Child Welfare Branch now consists of 1 Medical Officer, 1 Superintending Public Health Nurse, 18 Public Health Nurses (the designation of Health Visitors was changed to that of Public Health Nurse), and 12 Midwives, 2 of whom are Muslim women.

The section of the Medical Ordinance, No. 26 of 1927, relating to the practice of midwives came into operation as from July, 1930, and it is now an offence for any one not registered under this Ordinance to practice as a midwife, but a few unqualified and unregistered women still surreptitiously carry on and owing to the extraordinary difficulty of obtaining sufficient evidence it has so far not been possible to bring such offenders to book, but there is no doubt that their activities are now greatly restricted, and it is confidently hoped that they will gradually drop off in time.

The maternal mortality rate for the year under review was 29·0 per 1,000 births and the rate corrected for non-residents was 23·7, as against 21·0 for 1929, which compares unfavourably with the rate for England and Wales, which was 4·33 in 1929. The rate per 1,000 births from puerperal septicæmia was 13·6, as against 10·6 in the previous year. As stated in previous reports the deaths from puerperal septicæmia are mainly, if not entirely, due to the activities of unqualified midwives and until this class of women is entirely eliminated hopes of materially reducing the high maternal death-rate from this cause will be vain. That the unqualified midwife is responsible for the high incidence of puerperal septicæmia is seen from the following figures:—

Total number of births during 1930 (corrected for non-residents) ...	7,709
Number of deaths from puerperal septicæmia among Colombo residents	105
Death-rate per 1,000	13·6
Number of births conducted by Municipal Midwives	1,422
Number of deaths from puerperal septicæmia	3
Death-rate per 1,000	2·1

Whereas the death-rate from puerperal septicæmia is 13·6 per 1,000 among the cases attended to by both qualified and unqualified midwives, the rate is only 2·1 per 1,000 among the cases conducted only by qualified Municipal Midwives. The cases of puerperal septicæmia among the latter is due to dirty personal habits, dirty homes, nursing of patient by ignorant relatives, lack of clean linen, concurrent dysentery or diarrhœa, &c. One very great difficulty in keeping the case clean is the total lack of clean linen in the great majority of poor homes for the use of the lying-in woman. Both from poverty and under the belief that a woman in childbirth is unclean and defiling the oldest and dirtiest rags in the house are set apart for the patient's use. It would be a great boon to these poor people and also a means of preventing puerperal sepsis if funds could be found for supplying the really deserving cases with a small cheap outfit for both mother and infant.

Out of a total of 9,180 live births registered during 1930, 1,422 or 15·4 per cent., as against 14·0 per cent. in 1929, were conducted by Municipal Midwives; 3,438 or 37·4 per cent. took place in hospitals, and the balance 4,320 or 47·2 per cent. were presumably conducted both by qualified and unqualified midwives practising in the town. In spite of notice boards put up in tenement areas warning against employment of unqualified midwives and the offer of the free services of Municipal Midwives a large number of the poorer ignorant classes still have recourse to "handy women."

The infant mortality rate for the year under review was 179, as against 201 in the previous year. This is the lowest rate so far recorded but this rate cannot be regarded as a true rate unless corrected for non-residents for the reason that unless a child of a non-resident mother dies in the city within the first few days after birth its death will not be recorded in the city whereas its birth will be recorded. The rate when corrected for non-residents is 186, as against 208 the corrected rate for 1929. But for the floods in May the rate would have been better. (See Diagram 1.)

REPORT OF THE MEDICAL OFFICER, MATERNITY AND CHILD WELFARE, FOR 1930.

THE MEDICAL OFFICER OF HEALTH, COLOMBO.

I HAVE the honour to submit my report on the Maternity and Child Welfare work of my branch during the year 1930.

I assumed duties on July 10, 1930.

I have held weekly ante-natal clinics at Gintupitiya and Maligakanda centres and at each of the four Municipal dispensaries; here expectant mothers were examined and advised by me and treatment given when necessary.

Owing to the absence of a Medical Officer for some months before my assumption of of duties the attendance at the ante-natal clinics was very poor at the commencement; a change for the better, however, soon took place, and at present it is nothing unusual to attend on twenty or thirty cases each morning, particularly at Gintupitiya, Slave Island, and Modera.

1,272 ante-natal cases were attended to in all at the various centres from July to December. 394 at Gintupitiya, 289 at Slave Island, 196 at Modera, 168 at Wellawatta, 159 at Maligakanda, and 66 at San Sebastian.

1,418 infants who could not be breast fed and whose parents were too poor to provide suitable nourishment were supplied with free milk in the form of Lactogen or Sunshine Glaxo at the various distributing centres. The infants were also examined when necessary, regularly weighed, and their progress recorded.

The present staff consists of a Superintending Public Health Nurse, a resident Public Health Nurse, 17 Visiting Public Health Nurses, and 12 Midwives.

The Public Health Nurses are on duty daily (except Sundays and public holidays) and their duties are as follows :—

From 7·30 A.M. to 10 A.M., verify birth returns and visit babies and mothers.

From 10 A.M. to 11·30 A.M., a daily report is made of the routine done in the office attached to the centre.

From 2 P.M. to 4 P.M., routine house to house visiting in the slums, the purpose of this being—

(1) To instruct the poor in health matters, *e.g.*, advantages of cleanliness, precautions to be taken when infectious diseases exist in the neighbourhood, &c.

(2) To advise the poor when illness prevails in their houses, persuade such to make use of the hospitals, dispensaries, and child welfare centres.

(3) To advise pregnant mothers they come across to attend the centre.

(4) To advise mothers to bring their children under one year of age, who require proper feeding, to the centre and to help mothers to register their babies.

The Public Health Nurses have paid in all 99,981 visits and their work has been satisfactory.

Both Public Health Nurses and Midwives are efficiently supervised by Miss L. Wambeek, who is quite devoted to her work ; she has had the advantage of a special training in England in public health nursing, and has been instrumental in introducing since October last the card system of home visiting as carried on at Birmingham ; by means of which a record could be kept of the progress of a baby from its birth to the fifth year of age.

Twelve midwives are distributed for duty at the various centres, their services are given free to the poor, and are available at any time during the day or night.

The midwives are regularly instructed to take all antiseptic precautions and to perform their duties in the cleanest possible manner, they are also provided with a splendid outfit to enable them to practise aseptic midwifery, but all these precautions seem more or less wasted when consideration is taken of the fact that the patient is obliged to use soon after the confinement any available piece of cloth, as a diaper, which more often than not happens to be "far from clean." I can testify to this fact, having attended on some of these cases either to assist at an abnormal labour or to suture a torn perineum. This defect not only harms the patient but also serves the midwife as a reasonable excuse to bring forward everytime a case turns septic, and should be remedied with as little delay as possible. Any extra expense incurred would be more than compensated by obtaining better results and a reduction of the maternal mortality.

An extra midwife for relief duty is necessary at the Gintupitiya centre, the six on duty at present cannot cope with the work, particularly when one happens to be absent.

1,422 cases have been attended to in all by our midwives during the year and their work has been satisfactory.

Lectures are regularly given to the Public Health Nurses and the midwives at the Child Welfare Centre at Gintupitiya.

In conclusion I have to thank you for advice and assistance so cheerfully and readily rendered on several occasions and the whole staff for their ready co-operation.

CHAS. G. PEIRIS,
Medical Officer, Maternity and Child Welfare.

(49) *List of Cases conducted by Municipal Midwives, 1930.*

Name of Midwife.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Total for Year.
Angelina Fernando ...	6	18	10	—	—	—	4	15	12	14	1	12	92
P. Medlin Perera... ...	9	4	4	8	7	5	8	12	7	13	9	8	94
Emily Direckze	9	18	7	3	13	4	—	14	2	15	9	19	113
Roseline Perera ... *Beatrice Rajapakse ...	6	4	8	12	13	14	11	6	10	13	12	25	134
N. Dharmaratna	16	2	—	3	5	8	10	3	—	17	3	12	79
Mary Sathasivam... ...	—	10	18	3	4	—	10	4	2	15	18	13	97
D. M. Pallewella Hamine ...	21	10	16	13	8	12	14	12	16	18	8	2	150
J. A. M. P. Jayasinghe ...	6	—	5	27	9	10	5	1	19	8	25	10	125
Inche Juhary	17	20	15	20	30	19	14	17	26	24	29	29	260
J. Arul Mary	5	9	8	3	10	13	8	10	9	13	2	4	94
K. C. Perera	10	3	5	8	1	20	10	5	18	14	18	—	112
†D. B. Diaz Inoon Jariya	9	7	—	—	—	3	9	5	9	—	22	8	72
Total ...	114	105	96	100	100	108	103	104	130	164	156	142	1,422

* Acted for Roseline Perera from January 1, 1930, to February 17, 1930.
† Retired on April 28, 1930.

(50) *Statement of Expenditure on Milk supplied to Infants by the Child Welfare Branch during the Year 1930.*

Month.	Cow Milk. No. of Bottles of Milk.	Cow Milk. Cost of Milk. Rs. c.	Lactogen. No. of 3 lb. Tins.	Lactogen. Cost of Lactogen. Rs. c.	Sunshine Glaxo. No. of 1 lb. Tins.	Sunshine Glaxo. Cost of Sunshine Glaxo. Rs. c.	Total Cost. Rs. c.
January	1,084	433 60	27	108 0	—	—	541 60
February	988	395 20	24	96 0	—	—	491 20
March	1,092½	437 0	24	96 0	—	—	533 0
April	1,010½	404 20	12	48 0	—	—	452 20
May	—	—	48	192 0	—	—	192 0
June	—	—	96	384 0	—	—	384 0
July	—	—	96	384 0	—	—	384 0
August	—	—	24	96 0	48	64 0	160 0
September	—	—	120	480 0	168	224 0	704 0
October	—	—	228	912 0	—	—	912 0
November	—	—	96	384 0	120	160 0	544 0
December	—	—	192	768 0	—	—	768 0
Total	4,175	1,670 0	987	3,948 0	336	448 0	6,066 0

(51) *Work done by Public Health Nurses during 1930.*

Name.	No. of Houses visited.	Instructions *re* Infant Feeding.	No. of Tickets issued.	Municipal Midwives' Cases (visited).
Mrs. A. Cruse	5,813	1,269	40	42
Mrs. I. Zieseness	5,130	1,022	20	21
Mrs. I. Marsden	4,445	2,982	55	48
Mrs. L. G. Firth	10,000	3,997	200	150
Mrs. E. Meier	6,603	3,241	111	187
Miss E. Jansen	6,290	2,664	110	98
Mrs. V. Misso	6,176	2,955	220	64
Miss A. Schokman	7,231	4,354	57	108
Mrs. M. M. Samarasekera	5,376	1,811	13	104
Mrs. M. S. Perera	10,312	3,084	15	98
Mrs. M. Fernando	—	—	—	—
Mrs. F. E. M. Harris	8,896	4,426	54	102
Mrs. M. John	4,017	3,272	126	134
Mrs. I. Ferdinand	8,820	3,450	164	99
Mrs. Martha Perera	5,334	2,491	30	—
Mrs. M. M. Marshall	5,137	1,696	90	35
Miss Bastian Pulle	401	215	8	8
Total	99,981	42,929	1,313	1,298

XXX.—Staff Changes.

Dr. C. G. Peiris, M.B., C.M., and L.M. (Dublin), was temporarily appointed on July 10, 1930, to the post of Medical Officer-in-charge of Maternity and Child Welfare, in succession to Dr. (Mrs.) M. Lakshmiamma who resigned.

Bacteriological Laboratory.

Vide Annexure A for the Report of the City Microbiologist.

Analytical Work.

Vide Annexure B for the Report of the City Analyst.

Annexure C.

The Report on the Protection of the Interior of Ceylon from Plague with Special Reference to the Fumigation of Plague-suspect Imports.

Annexure A.

REPORT OF THE CITY MICROBIOLOGIST FOR 1930.

1.—LABORATORY.

The reconditioning of the extended building has been satisfactorily completed. It is now exceptionally well equipped for the general microbiological investigation of public health, veterinary, and economic problems connected with waterworks and sewage disposal.

2.—ANALYSIS OF ROUTINE WORK.

(a) General Distribution of Routine Specimens examined during 1930.

Clinical specimens	2,198
Town water	192
Rat-fleas for species distribution...	6,167
Rodents for plague :—	
Port Commission	3,606
Veterinary Department	16,293
Public Health Department	1,643
Veterinary Department :—	
Goats' blood for anthrax	975
Miscellaneous	72
Rats for Flea Index :—	
Veterinary Department	1,790
Port Commission	59
Total ...	32.995

(b) Distribution of Clinical Specimens.

	Examined for	Number Received.	Number Positive.
Diagnostic service for practitioners.	Enteric	327	141
	Tuberculosis	172	40
	Dysentery	274	49
	Diphtheria	71	13
	Hookworm	190	55
	Malaria	59	8
	Various	340	192
Public Health Department	Enteric	566	9
	Human plague	12	5
	Dysentery	40	2
	Diphtheria	52	4
	Hookworm	14	5
	Tuberculosis	8	—
	Malaria	3	—
	Various	70	18
	Total	2,198	541

Seventeen rectal swabs forwarded by the Council's dispensaries were examined for B. dysenteriæ and an atypical strain of Flexner's bacillus was isolated from one case.

(c) Distribution of Rodents examined for Plague in 1930.

(1) By Mode of Capture.

	Species.	Number examined.	Number infected.	Percentage infected.
Trapped rats	R. rattus	15,382	2	0·01
	R. norvegicus	2,862	4	0·14
	M. musculus	320	—	—
	Bandicoots	5	—	—
Rats found dead	R. rattus	60	3	5·00
	R. norvegicus	55	2	3·64
	M. musculus	4	1	25·00
	Bandicoots	1	—	—
Rats killed by Clayton machines	R. rattus	740	1	0·13
	R. norvegicus	987	—	—
	M. musculus	1,117	—	—
	Bandicoots	9	—	—
	Total	21,542	13	0·06

Four cats fowarded by the Public Health Department were examined for plague ; 1 was found to be plague infected.

(2) By Species and Source.

Species	Source	Trapped Alive. Number examined.	Trapped Alive. Number infected.	Trapped Alive. Percentage infection.	Found Dead. Number examined.	Found Dead. Number infected.	Found Dead. Percentage infection.	Killed by Fumigation. Number examined.	Killed by Fumigation. Number infected.	Killed by Fumigation. Percentage infection.
R. rattus	Veterinary Department	13,764	2	0·01	43	3	6·97	—	—	—
	Public Health Department	—	—	—	6	—	—	482	1	0·21
	Port Commission	1,618	—	—	11	—	—	258	—	—
R. norvegicus	Veterinary Department	2,440	1	0·04	38	1	2·63	—	—	—
	Public Health Department	—	—	—	15	1	6·66	851	—	—
	Port Commission	422	3	0·71	2	—	—	136	—	—
M. musculus	Veterinary Department	5	—	—	—	—	—	—	—	—
	Public Health Department	—	—	—	4	1	25·00	275	—	—
	Port Commission	315	—	—	—	—	—	842	—	—

Five bandicoots trapped, 1 bandicoot found dead, and 9 bandicoots killed by fumigation were negative for plague.

(*d*) *Monthly Flea Index.*

Month.	Number of Rats examined.	Flea Index.	Month.	Number of Rats examined.	Flea Index.
January	245	3·42	July	65	4·8
February	155	3·01	August	71	3·36
March	163	5·01	September	117	4·44
April	100	3·22	October	314	2·49
May	71	5·93	November	268	2·19
June	80	3·35	December	200	2·96

3.—Research Work.

I was compelled to take six months home leave on urgent private affairs during the year under review, necessitating an interruption in the research work carried over from 1929.

It has, however, been found possible to complete the annexed report on "The Protection of the Interior of Ceylon from Plague with Special Reference to the Fumigation of Plague-suspect Imports," which will be issued separately to the various authorities believed to be actively interested in general plague preventive problems.

While on leave I continued the identification of collections of rat-fleas for the preliminary rat-flea survey of Ceylon at the Imperial School of Hygiene and Tropical Medicine. Cultures of both *Xenopsylla astia* and *X. cheopis* from Ceylon were established at the Department of Medical Entomology. The survey is still in progress and it is hoped to complete it this year. An outline of the results obtained to date are shown in the above mentioned report. Attention is particularly directed to the discovery of the first focus of *cheopis* infestation in the interior of the lowland, viz., the bazaar area of Kurunegala where much rice and other grain mostly derived from the plague area of Colombo is stored. So far plague has not appeared in this area. I am of opinion, however, that the locality is ripe for a fairly serious outbreak unless vigorous anti-rat measures are prosecuted in the bazaars. *X. cheopis* has also obtained a footing at the naval port of Trincomalee.

En route to Europe an official visit was paid to the Guindy Institute, Madras, and an unofficial one to the Haffkine Institute, Bombay. I was thus enabled to get into close touch with two important developments of plague research which are among the first fruits of the Research programme outlined by the League of Nations Commission at Calcutta in 1927 of which I am a member. Lieut.-Col. H. H. King was good enough to give me full particulars of the results so far obtained from the rat-flea survey of Madras Presidency, most of which have already been reported in The Indian Journal of Medical Research. The findings are of great epidemiological interest and have important bearings on the plague position in Ceylon. Brief comments on certain points are included in the annexed research report.

At the Haffkine Institute, Bombay, Major W. J. Webster, I.M.S., took great pains to demonstrate his observations and the technique of his plague transmission experiments with *X. astia*, *X. brasiliensis*, and *X. cheopis*. His results have now appeared in The Indian Journal of Medical Research of October, 1930. He has confirmed the general conclusion, published in my memoir on the Parasitology of Plague, that rat-fleas of different species may be unequally efficient vectors of plague, their relative efficiency varying according to the climatic conditions.

Using large quantities of fleas under conditions permitting of both direct and indirect (non-specific) transmission both *X. astia* and *X. cheopis* transmitted continously, but when the number were reduced and the experimental technique approximated to that required for a strictly accurate quantitative comparison, it was found that *astia* is "a much less regular transmitter than either *cheopis* or *brasiliensis*." The general trend of recent Indian work supports the position I took up in the article on the flea-species factor in the above mentioned memoir, that *astia* will only enter into plague transmission in a state of nature when the *astia* index, *i.e.*, average number of *astia* per rat, is relatively high. Analysis of the data so far available suggests that the critical figure is probably between 6 and 7 at a mean temperature below 80°F. in moderately humid air. If this be true then large areas in Southern India, Ceylon, and Burma, where *astia* greatly predominate at a relatively low level of flea population, may be expected to remain almost immune from plague unless and until *X. cheopis* or possibly *X. brasiliensis* is introduced in grain and cotton from areas where these fleas are indigenous.

The investigation into hookworm infestation of sewage works in Colombo and Angoda and of the causes of hookworm disease among the employees of tropical sewage works is now nearly complete and it is hoped to report the results this year.

Quarantine of goats imported from India prior to slaughter was introduced in 1930. The disquieting discovery was made by the Acting Veterinary Surgeon, Mr. M. Crawford, that a small percentage of the carcases of goats slaughtered for human consumption were infected with anthrax. My assistant Mr. C. A. Woutersz isolated strains of *B. anthracis*, all highly virulent to guinea-pigs, from one spleen and two livers out of 41 specimens of goat spleen, liver, lung, and lymphatic gland. In addition a bacillus of the pasteurella group was isolated from no less than eight spleens, two lungs, one liver, and one lymph gland which also proved extremely virulent to guinea-pigs.

I have confirmed these observations and also tested a series of 60 unselected carcases for anthrax with negative results.

The research into the remarkable types into which these local strains of goat anthrax dissociate is being continued.

Further observations will be made on natural amœbiasis of the macaques and other monkeys of Ceylon watersheds as opportunity affords.

Experiments are in progress with new chlorine products and on the newly introduced "catadyn" process for the sterilization of water supplies.

L. F. HIRST.
City Microbiologist.

January 17, 1931.

Annexure B.

REPORT OF THE CITY ANALYST FOR 1930.

A total of 1,524 samples were examined during the year, of which 1,261 were milks, 193 town waters, 11 well waters, and 59 miscellaneous.

The city water supply showed no change from its usual standard of purity as far as chemical tests show. However, from a bacteriological point of view, the outlook is not quite so bright according to Dr. Hirst, the City Microbiologist, and chlorination of the water supply is to be carried out in the not too distant future.

Out of 11 well waters, the number condemned was 9 and 2 were shown as suspicious.

Three samples of water used for vegetable gardens were returned as heavily polluted from both animal and vegetable sources.

Arrack samples to the number of 10 were tested and 5 were found to contain more than the permissible standard of 0·25 grains per gallon of copper. In comparison with last year this is rather discouraging.

Out of 5 samples of vinegar tested 4 were not up to the United Kingdom standards and the remaining one was condemned as unfit for human consumption owing to the high copper content.

Two samples of flour were condemned owing to the presence of weevils.

Out of 9 samples of inferior teas 4 were tested as these represented the total and were all found to contain either some addition such as bicarbonate of soda to increase the colour of the infusion or were mixed with exhausted leaves or had been so carelessly treated in manufacture as to have lost a great part of the soluble constituents.

Such teas would have no sale in the United Kingdom and if found on the market the vendors would be prosecuted, but as Ceylon has no Food Laws and the teas are not actually harmful they continue to be sold without let or hindrance although obviously far below standard. If any article of food (excepting milk) is not convincingly harmful it is allowed to be sold in Ceylon. Although in some cases the price of the inferior article allows it to be bought by some who in the absence of the inferior could not afford the genuine, it makes for unfair competition against the genuine article as the man in the street has no way of telling the quality of foodstuffs except by use. Even when sophistication is present and proved by analysis, unless the article is unfit for human consumption the vendor is not punished.

1,261 samples of milk were tested. Out of these 625 passed and 636 fell below standard.

Since 1925, as is shown in the table below, the milk has been getting gradually worse as far as can be judged by the figures.

Year.	Total Number of Samples examined.	Number unadulterated.	Number adulterated.
1925	1.102	732=66·4 per cent.	370=33·6 per cent.
1926	1,163	755=64·9 per cent.	408=35·1 per cent.
1927	1,158	735=63·5 per cent.	423=36·5 per cent.
1928	1,237	751=60·7 per cent.	486=39·3 per cent.
1929	1,271	724=57·0 per cent.	547=43·0 per cent.
1930	1.261	625=49·5 per cent.	635=50·5 per cent.

1930 then has been a record year for milk adulteration not only in percentage of milk examined but a maximum adulteration of 81 per cent. was found which proves that the extra profit derived from watering milk exceeds any fines that may have to be paid.

Mere fining is obviously not the cure, and adulteration of milk in all forms will no doubt continue until cancellation of licence and imprisonment are used as deterrents.

Fat deficiency calculated on the milk as sold is slightly less this year than last.

The Laboratory, Turret road south,
Colombo, March 19, 1931.

A. E. PURVES,
Acting City Analyst.

Sample Index.

Months.	Town Water.	Well Water.	Miscellaneous.	Milk. (Total)
January	16	—	2 flours, 3 aerated waters	105
February	16	—	3 soda waters, 1 arrack	104
March	16	—	3 soda waters, 1 arrack. 1 disinfecting powder...	105
April	17	1	1 arrack, 3 soda waters, 1 tropical chloride of lime	103
May	16	—	1 dried milk powder, 1 arrack, 1 tea and buffalo milk for flour	98
June	16	—	1 soda water, 2 vinegars, 1 arrack, 6 teas, 1 lozenges, 2 condensed milk	105
July	16	—	1 arrack	106
August	16	2	1 ghee, 1 soda water, 1 arrack, 1 red powder	108
September	16	2	1 arrack	104
October	16	—	5 sewages, 1 "Perchloran" disinfectant powder, 1 arrack	109
November	16	6	1 arrack, 3 vinegars	108
December	16	—	4 teas, 3 waters from vegetable gardens	106
Total	193	11	59	1,261
			Grand Total	1,524

Milk as Sold—Fat Deficiency, 1930.

Months.	Total Milks.	Total below Standard.	1-10 Per Cent.	11-30 Per Cent.	+31 Per Cent.	Maximum.
January	105	26=24·8 per cent.	7	11	8	55·7 per cent.
February	104	30=28·8 per cent.	7	10	13	61·4 per cent.
March	105	19=18·1 per cent.	4	11	4	41·4 per cent.
April	103	28=27·2 per cent.	9	13	6	64 per cent.
May	98	22=22·4 per cent.	5	9	8	54 per cent.
June	105	22=21 per cent.	6	10	6	63 per cent.
July	106	28=26·4 per cent.	8	14	6	63 per cent.
August	108	46=42·6 per cent.	17	20	9	71 per cent.
September	104	32=30·8 per cent.	6	15	11	61 per cent.
October	109	23=21·1 per cent.	6	14	3	56 per cent.
November	108	20=17·4 per cent.	9	6	5	34 per cent.
December	106	22=20·8 per cent.	7	9	6	57 per cent.
Total 1930	1,261	318=25·2 per cent.	91=7·2%	142=11·3%	85=6·7%	71 per cent.
1929	1,271	345=27·1 per cent.	100=7·9%	166=13 %	79=6·2%	95·7 per cent.

Milk Analyses.

Added Water 1930.

Months.	Total Number of Samples examined.		Pass.	1-10 Per Cent.	11-30 Per Cent.	+ 31 Per Cent.	Maximum.
January	105	No. of samples	60	28	15	2	38 per cent.
		Per cent. of samples	57·1	26·7	14·3	1·9	
February	104	No. of samples	58	30	10	6	65 per cent.
		Per cent. of samples	55·8	28·8	9·6	5·8	
March	105	No. of samples	51	33	15	6	68 per cent.
		Per cent. of samples	48·6	31·4	14·3	5·7	
April	103	No. of samples	46	37	12	8	54 per cent.
		Per cent. of samples	44·6	35·9	11·7	7·8	
May	98	No. of samples	45	33	16	4	57 per cent.
		Per cent. of samples	45·9	33·7	16·3	4·1	
June	105	No. of samples	51	37	9	8	62 per cent.
		Per cent. of samples	48·6	35·2	8·6	7·6	
July	106	No. of samples	51	36	13	6	48 per cent.
		Per cent. of samples	48·1	33·9	12·3	5·7	
August	108	No. of samples	45	37	20	6	81 per cent.
		Per cent. of samples	41·7	34·2	18·5	5·6	
September	104	No. of samples	48	36	10	10	66 per cent.
		Per cent. of samples	46·2	34·6	9·6	9·6	
October	109	No. of samples	63	32	12	2	37 per cent.
		Per cent. of samples	57·8	29·4	11·0	1·8	
November	108	No. of samples	58	37	10	3	46 per cent.
		Per cent. of samples	53·7	34·2	9·3	2·8	
December	106	No. of samples	49	43	10	4	63 per cent.
		Per cent. of samples	46·2	40·6	9·4	3·8	
Total 1930	1,261	No. of samples	625	419	152	65	81 per cent.
		Per cent. of samples	49·6	33·2	12·1	5·1	
1929	1,271	Per cent. of samples	56·9	26·4	10·3	6·4	74 per cent.

Well Water, 1930.

Months.	Well Waters.	Pass.	Condemned.	Suspicious.
January	—	—	—	—
February	—	—	—	—
March	—	—	—	—
April	1	—	1	—
May	—	—	—	—
June	—	—	—	—
July	—	—	—	—
August	2	—	2	—
September	2	—	1	1
October	—	—	—	—
November	6	—	5	1
December	—	—	—	—
Total	11	—	9	2
Grand Total	11			

Annexure C.

REPORT ON THE PROTECTION OF THE INTERIOR OF CEYLON FROM PLAGUE, WITH SPECIAL REFERENCE TO THE FUMIGATION OF PLAGUE-SUSPECT IMPORTS.

CONTENTS.

GENERAL INTRODUCTION.

Seventeen years ago plague was brought to Colombo from Rangoon *viâ* Negapatam in shipments of rice. Rangoon is the source of most of the half million tons of rice and fifty thousand tons of miscellaneous grain imported yearly to Ceylon through Colombo Port. Much of this rice is consigned to estates in hill country Ceylon lying between 1,500 and 5,000 feet elevations where the climatic conditions are favourable to the spread of plague, according to the experience of other countries, and where a particularly dangerous carrier of the plague bacillus, the flea *Xenopsylla cheopis*, is well established on the boutique rats.

The danger of rice as a vehicle of plague was early recognized, and as soon as possible after plague broke out in the old Sea street godowns of Colombo, where Rangoon rice used to be stored, the wholesale trade in this commodity was transferred to specially constructed granaries under the charge of Government. By this means it was hoped to avoid a rapid extension of rice-borne plague to the interior. The wholesale trade in other grains, some of which also comes from plague infected sources, is still carried on in private and unsatisfactory premises in the Pettah district.

From the commencement the distribution of plague in Colombo has been irregular, being practically confined to the Sea Street-Pettah district, and to the vicinity of markets where imported grain is stored and where the rats are infested with the imported flea *X. cheopis*. Twice it appeared that strenuous anti-rat and rat-flea campaigns in these plague areas had been successful and hopes were raised of freeing Ceylon entirely from this dangerous disease, only to be disappointed by the re-importation of a fresh strain of infection through the harbour and a lively recrudescence of rat and human plague.

Recently outbreaks have become more frequent in the Central Province, originating usually in the vicinity of grain boutiques. Hitherto they have been localized and suppressed by very drastic measures in the face of increasing opposition. There is a danger that plague will eventually establish itself in the highlands of Ceylon as it has done already in the Java hills. It is believed that this would have happened long ago but for the existence of a natural barrier to the spread of plague in lowland Ceylon, where, as in many parts of lowland Madras, the indigenous rat-flea *Xenopsylla astia* occurs on *Rattus rattus* unmixed with other species in numbers varying from two to five per rat. Evidence is rapidly accumulating in favour of the writer's view that this degree of *astia* infestation is inadequate to maintain plague among domestic rats.

Unfortunately, both in low-country Ceylon and Madras, *X. cheopis* is slowly becoming established on the rats of bazaars and mills containing imported grain and cotton. This *cheopis* invasion tends to break down the relative immunity of pure *astia* areas to plague and to lead to outbreaks during the season of the year favourable to the activities of the foreign flea.

It would appear, then, that our present measures are inadequate not only for the eradication of plague from Colombo but also for the twofold protection of highland Ceylon from grain-borne plague infection and of lowland Ceylon from further invasion by the most efficient insect carrier of the plague bacillus.

Two main lines of defence are available against both perils, fumigation of plague-suspect goods and rat-proofing of premises where they are stored. These measures should be regarded as complementary to one another. Clearly it would be futile to fumigate goods and store them in rat-ridden premises, possibly exposed to fresh infection from an internal source.

The efficient rat-proofing of premises containing produce such as rice and other grains conducive to rat breeding has received much attention in Ceylon. The grain regulations incorporated in the Quarantine and Infectious Diseases Ordinance, 1897, prescribe the structure of grain stores. Detailed amendments are now under consideration by the Railway Goods Sheds Committee appointed by Government.

The present report deals more particularly with the destruction of rodents and their fleas by fumigation of imported produce. The experimental work was done under a special appropriation from the Port Commission Fumigation vote: together with the rat-flea surveys still in progress and incompletely summarized herein, it forms part of the Plague Research Programme now being carried out in many parts of the East under the auspices of the League of Nations.

An attempt will be made to indicate the source of the more dangerous imports and to show how the various kinds of grain may be fumigated with cyanide gas so as to free them from rats and fleas without injury to the goods and without undue interference with commercial enterprise.

In Ceylon, for practical plague preventive purposes, attention should be concentrated on the grain and cotton trades. It is impossible in practice to close every conceivable avenue of plague importation. Nor is it advisable or commercially feasible to make the attempt. All the available epidemiological evidence points to the conclusion that a high degree of safety against plague may be assured by adopting certain well recognized safeguards.

The importance of taking every reasonable and practicable step to safeguard Ceylon against plague importation from sources overseas can scarcely be exaggerated. There can be little or no doubt that, but for such re-importation of the infection, the disease would have been got rid of in Colombo and all danger of the establishment of a new endemic focus in the highlands would have long since been averted.

I.—Mode of Transference of Plague Infection.

Though the association of human plague with mortality among rodents has been recognized since Biblical times and the danger of commercial intercourse with plague infected regions since the reign of Justinian, 543 A.D., yet, till recently attention has been focussed upon man himself as the direct disseminator of the infection, plague being regarded as a disease directly contagious in the same sense as smallpox or scarlet fever. Hence the importance formerly attached to the inspection of travellers by land and sea from plague infected regions, to isolation of the sick and to segregation of contacts. We now know that only the pneumonic type of plague is infectious by inhalation and that it is only under exceptional circumstances that any form of plague can be transmitted directly, *e.g.*, post-mortem coolies dissecting bodies of septicæmic plague cases frequently become infected through the skin.

Recent research has demonstrated that bubonic plague is primarily a disease of rodents carried by fleas. So far as maritime commerce is concerned, the rat is the important rodent and for all practical purposes it may safely be said that the presence of rat-fleas in sufficient numbers is essential for the continuous spread of bubonic plague. It is only as a flea carrier, or under very exceptional circumstances as a flea infector, that man himself comes into play. No danger whatever need be feared from a human bubonic or septicæmic plague patient once he is freed from fleas, unless he happens to develop pneumonia. Some danger attaches to flea-infested personal effects and this source of infection certainly requires to be taken into account, especially in connection with the wholesale evacuation of plague stricken quarters in localities where the rats bear many fleas. Petrie (1923) believes that plague fleas may be distributed by the disinfecting staff of a public health authority. Swellengrebel (1913), however, only found seven *X. cheopis* among the clothing of 1,829 inhabitants of Malang, Java, of whom 393 were infected with plague. The conditions are somewhat similar to those of Kandy in Ceylon.

In brief, human migration may be a factor in the spread of plague, but it is one which is comparatively seldom of primary importance.

Merchandise does not convey the infection directly as was thought formerly. The *Bacillus pestis* survives but a short time outside the bodies of rat, flea, or man. The danger of any particular kind of merchandise acting as a vehicle for the conveyance of plague is proportionate to the extent to which it has been infested by plague rats and fleas. Experience shows that it is the movement of goods from premises which are, or have lately been, the scene of a rat epizootic that is most likely to lead to the distribution of plague. Of goods the most dangerous are those most attractive to rats or those giving the greatest shelter to fleas.

The following is extracted from the "Norman White Draft" for the Far Eastern Sanitary Convention :—

> "The nature of the goods or merchandise likely to harbour rats (plague-suspicious cargo) shall, for purposes of this section, be deemed to be the following, namely :
>
> "Rice or other grain (exclusive of flour) ; oilcake in sacks ; beans in mats or sacks ; goods packed in crates with straw or similar packing material ; matting in bundles ; dried vegetables in baskets or cases ; dried and salted fish ; peanuts in sacks ; dry ginger ; curios, &c., in fragile cases ; copra ; loose hemp in bundles ; coiled rope in sacking ; kapok ; maize in bags ; sea-grass in bales ; and bamboo poles in bundles."

To these might be added, horse and cattle fodder, gunny bags, rags and hides, and cotton loose or in bales. The last three afford effective harbourage to rat-fleas.

During the anti-plague campaign in Porto Rico in 1912 one of the first steps taken to prevent the spread of plague inland was to open and re-pack all crates bound from San Juan to the interior of the island. "The discovery of a number of rats in these crates caused us to begin the fumigation of all such freight arriving from the Canary Islands, which were believed to be the original source of infection." (Grubbs, 1923.)

The experience of the United States Quarantine authorities led them to attach importance to bags of almonds or crated vegetables in connection with their fumigating operations designed to protect such stations as Cristobal Canal zone and New York against the introduction of plague from Payta, Peru or Barcelona, Spain.

Fumigation is regarded as the chief defence of the United States against bubonic plague.

Grain is the most important vehicle of plague infection since it is the favourite food of rats and its debris forms a suitable diet for the larvæ of the plague-carrying fleas. Free access to grain, therefore, invariably leads to a great increase in rat and flea numbers and to conditions favouring a rat epizootic. Hence it is not surprising that in the words of Norman White (1920) "each year's experience has brought fresh illustrations of the excessively great importance of the movements of grain and other merchandise in the transference of plague infection from place to place."

Plague has never persisted for any length of time in Colombo except in the vicinity of grain stores infested with the imported flea, *Xenopsylla cheopis*. The premises where plague first broke out in Kandy in 1920 were next door to a boutique where much grain brought up from Colombo was stored, the partition wall was riddled with rat-holes and many rats had died in the vicinity. Both outbreaks at Galle were also traced to imports of grain from overseas. These examples might be multiplied from local experience.

The experience of the Dutch authorities in Java has been very similar. Rat mortality was first observed in a rice godown at Surabaya and rice was the chief vehicle for transporting the infection to the interior. In 1918 plague appeared at Belawen, a port in Sumatra. The disease originated in a store filled with rice from Rangoon. Swellengrebel (1913) arrived at the following conclusion as a result of his observations on plague in East Java :—

> "The only merchandise, the maximum import of which coincides more or less closely with new conquests of plague is the rice from British India and Southern China."

Granted that grain of some kind or other is the principal medium for the transference of plague from place to place, the question arises whether greatest importance should be attached to the rat or to its fleas as the actual vehicle of the plague bacillus.

If an unprotected rat-ridden and plague infected granary is searched, dead rats are seldom found in the midst of the grain bags nor do rats burrow into the interior of the bags themselves as frequently as was formerly imagined. They tend to die in their nests in odd holes and corners. Moreover, in carrying plague from one spot to another, it is only the live rats that come into consideration. But, as Flu (1921) points out, the proportion of live plague infected rats caught in the course of an epizootic is usually only a very small fraction of the total live rats examined. Grijns calculated that, during a moderate epizootic of plague about 12,000 live rats would have to be examined to find one infected with plague. The highest figure recorded in Colombo is 2·38 per cent. for *Rattus norvegicus* in 1914, the year of greatest epizootic intensity, a more usual figure would be 2 per 10,000.

The greater the rat population of a given group of premises the more numerous the fleas. In fact, the average number of fleas per rat tends to increase when rats are aggregated together in unprotected granaries where food is close at hand. In sparsely populated districts the rats are compelled to make wider excursions in search of food and scatter their fleas over a wider area. If exact counts are made, it will be found that the average number of fleas per rat on the outskirts of a city is less than for the same species of rat in the more crowded quarters. On an average, rats dying of plague are infested with many more fleas than rats in normal health (1908).

Grain traffic facilitates the transport of fleas. If guinea-pigs be released in rat-ridden granaries, they will pick up rat-fleas even when live rats are present and still more readily when an epizootic is in progress. According to the observations of Flu in the Dutch East Indies, the course of events is somewhat as follows :—"On the death of the rat the fleas leave its body and a part of them reach the rice bags and hide themselves between the strands of the bags and even make their way inside. A few of these fleas will be infected with plague. On arrival of the consignment at destination, they will transfer themselves to the nearest rat, or failing that, to man."

The extent of territory over which the infection may be possibly conveyed by rats and fleas depends altogether upon circumstances. A rat dies usually within a week of being bitten by the infected flea. The length of time its fleas will survive separated from their host varies enormously with the climatic conditions.

The data in respect of the maximum longevity of starved plague infected *X. cheopis* under tropical conditions are inadequate, but it is safe to say that the female may survive up to one week and the male up to four days. Under normal circumstances only part of the fleas infected after biting a plague-stricken rat can transmit the disease—the proventicular valve must first be thrown out of action by plague growth—such fleas have a very short life in dry or hot air, but in a cool moist atmosphere they may live for weeks. Transmission of plague has been obtained with the same batch of *X. cheopis* in the host's presence up to the 23rd day in Colombo and up to the 19th day at Surabaya on the Java coast. In the hills the duration of infectivity for both fed and unfed fleas would be very much longer.

The available evidence indicates that when an overseas source of infection is but a few days removed an infected flea may be readily transferred directly in grain from the port of origin to the port of entry. Otherwise it may be inferred that a plague epizootic has occurred among the rats on ship-board. The link between the ship epizootic and the shore rats or the rats of the lighters into which cargo is loaded or unloaded may be a plague rat but is much more likely to be a plague flea.

At Colombo the mooring of ships away from the quays and the use of lighters for transferring cargo from ship to shore must considerably reduce the importation of rats. Nevertheless, one foreign species, *Rattus norvegicus*, has established itself near the harbour, but *R. rattus rattus*, the true black rat, common on ship-board and in foreign ports, and such characteristic species as *R. concolor*, common in the port of Rangoon and the ports of Dutch East Indies, are seldom found in the Customs premises or Government Granaries.

As regards internal sources of plague in Ceylon, in these days the infection may be transferred to any part of the Island by motor lorry or rail in the body of either rat or flea from any rat-ridden premises where plague is prevalent.

It would appear, then, that the spread of bubonic plague is usually the result of the passive transference of rats and fleas in merchandise conveyed by ship or lighter, railway truck, motor lorry, or bullock carts and in mountainous districts not infrequently in baskets of produce borne by coolies or elevated along ropeways.

Plague may be spread by the migration of rats. It is clear, however, that this factor must be of minor importance in Colombo and low-country Ceylon. If domestic rats moved freely from their homes both imported foreign species of fleas and imported infection would soon be widely and more or less uniformly distributed all over the town, but, as a matter of fact, the distribution of both, though irregular, has nevertheless remained fairly constant for many years. Experiments by Petrie in Egypt and the observations of the Dutch in Java indicate that the common domestic species of rats are not in the habit of wandering far from their customary haunts. The imported rat already referred to, *Rattus norvegicus*, wanders further abroad than the indigenous low-country species, *Rattus rattus kandianus*, and this may explain the greater extent and persistence of plague and the more uniform distribution of the flea *Xenopsylla cheopis* in the plague endemic area in Colombo, where *R. norvegicus* is relatively common. Wholesale migration of rats is a phenomenon most commonly observed on the margin of cultivation. The rats go out into the fields when crops approach maturity and return to town or village after the harvest has been reaped. In certain parts of Madagascar the annual recrudescence of plague is associated with the flooding of the rice fields when rats take refuge in the towns.

Should plague infection gain a footing among true field rodents, such as the squirrels and gerbilles, their movements become the most important of all the factors governing the spread of plague. Field rodent plague is essentially a disease of temperate climes, spread by the migratory movements of the rodents themselves. The fleas are mainly of the nesting type spending most of their time in the nest or burrow rather than on the body of the rodent. Under temperate conditions infected field rodent fleas of many species may survive for months unfed in burrows deserted by their hosts, which commonly emerge upon the surface to die of plague. In course of time the burrows become re-inhabited, these nesting fleas then serve as a reservoir of plague infection. In the Steppes of Southern Russia and Manchuria, subject to a severe winter climate, infection may be carried over the cold weather in the bodies of the hibernating rodent.

In the case of certain plague-suspect goods, such as cotton, gunny bags, rags, and hides, infection may be regarded as almost exclusively flea-borne. Recent observations in Ceylon and Madras indicate that cotton is particularly apt to carry fleas and this material has been incriminated as a vehicle of plague infection elsewhere (notably Japan).

It is very significant that the only premises on the outskirts of both Colombo and Madras cities where the foreign flea *X. cheopis* is found in large numbers (over 60 per cent.) on the rats are, in each case, mills using much cotton imported from *cheopis* infested areas.

In view of the amount of space devoted in this report to the consideration of the results of rat-flea surveys in their bearing on the transference of plague, a brief discussion of the parasitological principles involved may not be out of place.

The Indian Plague Commission showed that a general relationship exists between rat-flea numbers, as evidenced by average catch of fleas per rat—general flea index—and the seasonal and regional prevalence of plague, *i.e.*, more fleas more plague. Thus during the spring plague season in the plains of the Punjab and the United Provinces *R. rattus* flea indices as high as 20 have been secured. The plague epidemics in this region are of a devastating type but come to an abrupt termination when the flea index falls towards a minimum of about 2 during the hot weather. After an epidemic commencing at the beginning of the period of high flea population in this type of station it may take years to restore the rat population to a level permitting of another large outbreak. In the meantime the region may appear to be temporarily immune from plague. The seasonal periodicity is primarily governed by the effect of variations in the drying power of the air on flea breeding and flea survival. In a maritime city, such as Bombay, where the *R. rattus* flea index remains more or less stationary round about 4 (nearly all *X. cheopis*) the disease tends to recur annually at a lower level of epidemicity and the seasonal prevalence of plague is mainly governed by the effect of low minimum temperature on the transmitting power of the flea.

In countries, such as Egypt, where the rat fleas are almost exclusively *X. cheopis*, the relation between flea numbers, climatic conditions, and plague is particularly clear. According to Petrie the favourable range for *cheopis* reproduction and high *cheopis* index lies between 20-25°C. with a saturation deficiency lying between one and ten millibars of mercury.

Till 1913 it was believed that *Xenopsylla cheopis* Roths. was practically the only Indian rat flea. In November of that year the writer pointed out that a newly discovered species *X. astia* Roths. was the sole rat flea found in the then plague immune ports of Madras and Colombo. He suggested that both fleas would probably be found to carry plague, but that the mysterious immunity of parts of India, Burma, and Ceylon from plague could be explained on the hypothesis that *X. astia* was relatively inefficient. It was not till 1919 that Cragg took up the investigation of this hypothesis and instituted the first flea survey of India. His preliminary results on a crude percentage basis were of a confirmatory character.

Cragg (1923) pointed out that the specific flea index was the proper criterion to adopt in comparing flea prevalence on the same species of rat in different localities. The percentage figures formerly used in flea surveys will only suffice for reigons, such as Colombo, where the seasonal variations in climate and number of fleas per rat are comparatively slight and the results cover the whole range of *cheopis* prevalence from zero to a figure adequate for endemic plague.

In the introduction to Part I. of his Researches on the Parasitology of Plague (1926) the writer pointed out that " In Colombo the *cheopis* index usually lies between one and two in areas where plague is spreading." This index is for *Rattus rattus kandianus* in association with an *astia* index between two and three.

Grubbs (1927), independently suggested, on the strength of an analysis of the results of flea surveys of North American ports, that " it may be entirely premature to state that one *cheopis* is the critical flea index but possibly this is near enough to serve as a basis for further investigation." In North American *C. fasciatus* and *L. musculi* are the indigenous fleas, and when their numbers are exceptionally high they also must be taken into account as possible transmitters of the plague bacillus.

As regards regions where *X. astia* is found alone several independent lines of evidence suggest that the critical figure for this species is about seven ; *i.e.*, sporadic outbreak of *astia* borne plague may follow the importation of the infection when there are more than seven fleas of this species per rat.

A specific flea index represents the average number of a given species of flea per given species of rat. The actual variations in ecto-parasitic flea populations would be more accurately represented by frequency distribution curves. The average, however, suffices for practical epidemiological purposes.

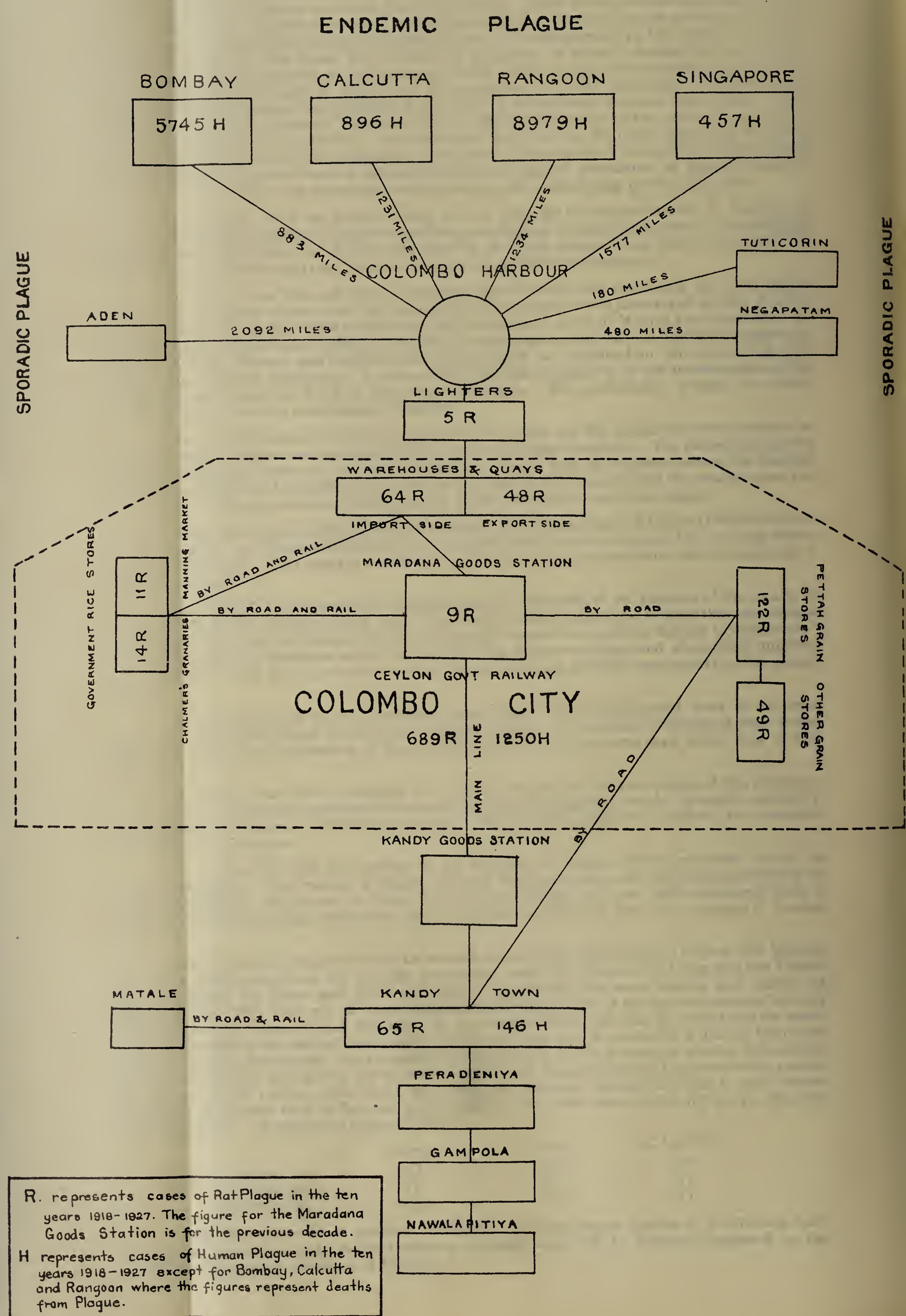
It is essential that the species of rat trapped for plague survey purposes should be properly identified. The rats of a locality do not vary much as a rule in their susceptibility to plague inoculation, but owing to their very diverse habits they not only commonly show a different distribution of flea species but play an altogether different part in the spread of human plague.

The systematic flea surveys so far carried out on a flea index basis in Ceylon and Madras, as well as those carried out on a crude percentage basis for All-India by Cragg and the United Province survey by Dunn and Mital all apply to practically the same species and variety of *Rattus rattus*. The grey rat of Great Britian and Europe occurs as an imported species in large numbers both in Colombo and Bombay. It is a much heavier rat than *R. rattus* and its larger skin surface bears a correspondingly greater number of fleas and is subject to a heavier incidence of plague in both these ports. In Colombo *X. cheopis* and *X. astia* occur in similar proportions on both *rattus* and *norvegicus*, but in both Bombay and Rangoon *cheopis* has a definitely greater predilection for *R. rattus*, while mole rats, such as *Gunomys bengalensis*, bear a much higher proportion of *X. astia* both in Bombay and Rangoon. The mean specific flea indices for Bombay are shown below. Webster and Chitre (1930).

		X cheopis.		*X. astia.*		*X. brasiliensis.*
R. rattus	...	3·7	...	0·5	...	0·2
R. norvegicus	...	4·4	...	2·5	...	0·0
Gunomys Sp.	...	2·2	...	7·3	...	0·1

The importance of an accurate distinction between rodent species in distributing both the flea survey results and plague incidence epizootic data will be further illustrated in the discussion of the plague situation in Rangoon.

DIAGRAM ILLUSTRATING PLAGUE COMMUNICATIONS



The next point to consider is the comparative significance of flea indices for different species of fleas. The total flea population of given premises is made up of three components, the fleas found on the rat itself, those in the rat's nest or burrow, and the free wandering fleas. Fleas do not remain permanently on the body of their host but tend to scatter for egg laying and other purposes. Rats are always losing fleas and taking others up again. It follows that an *astia* index of 1 per rat may represent quite a different fraction of the total flea population capable of entering into plague transmission than the same index for *cheopis*. As a matter of fact there is clear evidence that if rats previously freed from fleas are allowed to wander in premises containing cotton or grain in gunny bags infested with both *astia* and *cheopis* they pick up a higher proportion of the *cheopis*.

Again, rodent fleas may be roughly divided into two categories, the ecto-parasitic and the nesting, *i.e.*, those spending a large proportion of their time on the body of the host and those mainly found in the nest or burrow. There is no evidence that flea counts taken from field rodents outside their nests have much significance in the epidemiology of field rodent plague.

Finally, it should be realized quite clearly that the specific flea index and frequency distribution of fleas for the same host varies very markedly not only with climate but also with age and weight of host and type of premises trapped. According to observations in Java flea indices may be temporarily increased by the occurrence of a severe epizootic of plague among the flea yielding rats. Intensive poisoning campaigns seem to have a similar effect. Speaking generally heavily rat-infested granaries or bazaars show the highest flea indices and well constructed domestic premises in rural districts the lowest. In general the more widely scattered the rat population the lower the average number of fleas. It will be clear from the above that the total flea population of a given set of premises depends on the rat population, commonly measured by number of rats caught per 100 traps set. By multiplying this factor with the flea index figures, an index representing the gross ecto-parasitic flea population is obtained.

The attention of health officers is drawn to the recently published reports on the Rat-flea Survey of Madras Presidency (King and others 1929, 1930, 1931). This extensive survey is the first to be carried out in India in which due recognition is given to two vitally important points, the adoption of a reasonably satisfactory criterion of flea species prevalence in the regions under survey, viz., the specific flea index, and the necessity of making a clear distinction between the types of premises trapped.

These Madras results have important bearings on the transference of plague infection, particularly in countries where the indigenous rat-flea is a poor carrier of plague, but which are in active commercial intercourse with *cheopis* infested regions. The pioneer work in Colombo on the double danger of importing grain from plague infected and *cheopis* infested sources into pure *astia* zones has been confirmed. It is probable that an analogous risk attends the introduction of *cheopis* infested grain or cotton into the Ceratophyllus and Leptopsylla infested ports of temperate climes, especially in the summer time. The results of this survey also show that cotton, weight for weight, is an even more dangerous medium for *cheopis* transference than grain. It is fortunate therefore that in the case of Ceylon cotton imports only amount to about 20,000 cwts. per annum.

It is now clearly established that the importation factor both in Madras and Ceylon is more potent than the climatic in determining the distribution of *cheopis* and plague. Once *cheopis* has become established on the rats of the bazaars, plague may become endemic in the towns and villages of the Madras plains while sporadic mild importation outbreaks of pure *astia* borne plague may occur when the *astia* index is exceptionally high.

II.—Plague Communications.

1.—The Chain of Infection associated with Grain Importation.

The success of measures directed towards the safeguarding of any part of Ceylon from introduced plague clearly depends on an accurate knowledge of the probable sources of infection and of the channels along which it is likely to flow.

Reference should be made to the diagram purporting to represent the potentialities. It will be clear from what has already been said on the mode of transference of plague infection that not only the incidence of plague in the sources of the particular produce suspected to be acting as a vehicle of the infection, but the amount of the produce and the season at which the bulk of it reaches Ceylon must be taken into account. The presence of a raging epidemic of plague in port A will be of little significance to port B if there is no active commercial intercourse between A and B. Similarly, plague suspect produce imported to B will be most dangerous if it arrives at the season most favourable to the activities of the local plague flea. Thus Hicks (1927) attributes the relative freedom of Shanghai from plague to the fact that the plague season of this city coincides with the off-plague season in the south Chinese ports, which are the most probable sources of imported infection.

As already indicated the sources of plague overseas and the kinds of cargo which may shelter plague rats and fleas are so numerous that, in practice, it is impossible to frame an absolutely tight scheme to prevent the importation of plague infection. What should be done is to concentrate on the elimination of the principal risk. For Ceylon the dictum of Norman White seems to hold good—"The control of the grain trade and the proper storage of grain are almost synonymous with efficient plague preventive measures."

TABLE I.

The amounts of Rice imported by Months during 1927, from all sources.

Months.	Quantity in Cwt.
January	614,342
February	604,139
March	1,071,446
April	919,177
May	668.059
June	646,870
July	649,404
August	789,349
September	826,913
October	666,549
November	793,216
December	837,776
Total	9,097,240

TABLE II.

Source of Rice Imports, 1927.

Port of Origin of Imported Rice.	Number of Bags Imported.	Port of Origin of Imported Rice.	Number of Bags Imported.
Rangoon	4,480,315	Other ports in Asia	454,412
South India	702,775	Other ports in India	1,205
Coconada	385,623		
Calcutta	138,929		
Bangkok and Mauritius	11,643	Total	6,183,695
Bombay	8,793		

TABLE III.

Amount of Grain and Forage imported into Ceylon during 1927.

Country of Origin.	Gram.	Dhall.	Beans.	Bran and Pollard.	Poonac.	Hay and Straw.	Other food-stuffs for animals.	Cotton Seed.
	Cwt.	Cwt.	Cwt.	Cwt	Cwt.	Cwt.	Cwt.	Cwt.
United Kingdom	—	—	20	—	—	40	308	—
Australia	—	—	—	382	—	8,754	383	—
British India	71,937	229,801	944	129,542	383,456	23	251	18,134
Burma	38,925	—	11,810	6,081	—	—	—	3,703
Straits Settlements	696	—	9,817	—	877	—	—	—
Hong Kong	—	—	1,659	—	—	—	—	—
China	—	—	17,531	—	—	—	—	—
Java	—	—	280	—	—	—	—	—
Madagascar	—	—	7	—	—	—	—	—
Miscellaneous	102	—	10	52	—	3	2	—
Total	111,660	229,801	42,078	136,057	384,333	8,820	944	21,837

TABLE IV.

Exports from Rangoon to Ceylon.

	Year 1929. Tons.	Year 1930. Tons.
Rice	318,262	316,375
Beans	936	875
Peas and Dahl	936	654
Gram	821	470
Paddy	274	323
Sooji and Millet	6	16
Total	321,235	318,713

TABLE V.

Exports from the Outports of Burma to Ceylon.

	1929.		1930.	
	Paddy. Tons.	Rice. Tons.	Paddy. Tons.	Rice. Tons.
Akyab	29,654	857	14,403	942
Bassein	Nil.	5,035	Nil.	6,482
Moulmein	Nil.	Nil.	Nil.	1,250
Total	29,654	5.892	14,403	8,674

Reference to Table II. shows that more than 70 per cent. of the huge quantity of rice imported to Ceylon comes from Rangoon, till recently the most heavily plague infected Oriental port.

Rice is the chief agricultural commodity produced by Burma. During the years 1928–29 no less than 12,208,896 acres of the crop were sown, matured, and assessed, yielding 7,164,308 tons of unhusked rice, while 2,940,822 tons of rice were actually exported from Rangoon and the Burmese outports, Akyab, Bassein, and Moulmein during, 1929. For the Ceylon share of Burmese grain exports, see Tables IV. and V. supplied by the Commissioner for Customs, Rangoon. According to information obtained on the spot about 60 per cent. of the Colombo rice exports are milled in Rangoon and 40 per cent. in up-country mills, of this about 10 per cent. comes by boat from Delta districts, 20 per cent. by the Mandalay railway line, and 10 per cent. by the Prome railway line.

It is important to note that in 1929–30 only 19 per cent. of the 2,385,516 tons of rice shipped from Rangoon passed over the premises of the Port Commission, 452,615 tons lightered from the foreshore and 781 tons only shipped from the wharves. The bulk of the rice is lightered from the creeks opening into the Rangoon river where the 49 rice mills are situated, viz. the Kemmendine reach, the Pazundaung creek, the Kanaungtoe creek and the Dalla creek.

It would appear that the districts where most of the South Indian rice and the rice exported from Calcutta and Coconada is grown are but little infected with plague. The disease is almost always at a low level of incidence along the east coast of India. Coconada is but little subject to plague. Madras, and of late years Calcutta, are almost immune.

About 4,000 bags of muthusamba rice, together with small quantities of gram, dahl, and pulse, arrive monthly *viâ* Dhanushkodi and Talaimannar. Most of the rice is conveyed by rail from Talaimannar and unloaded in the Government Granaries, but small quantities are sent direct to Galle, Jaffna, Negombo, and Kandy. The source of the grain according to the records of the Port Commission is as follows: Nagapatam, Kuddulam, Karikal, Colonoor, Shiyali, Chidabaram, Koradacheri, Tandarati, Tinnevilli, Tiruturaipoondi, Maunargudi, and Kudalai. The Director of Public Health, Madras, states in a letter dated October 22, 1928—"that the localities mentioned are not known to have suffered from any epidemics of plague." Grain is brought in increasing quantities to the small Ceylon outports, Kayts, Trincomalee, and Galle, mainly from small ports in Madras, but a few boats bring rice direct from Rangoon, Akyab, or Moulmein.

Both in source and variety the imported grains, other than rice, are of a very miscellaneous character. Much of the dahl comes from Calcutta, large amounts of gram from Karachi, and green gram from Shanghai and Hong Kong. It will be noted that Burma has a good share in the imports of gram and beans.

Karachi is subject to plague and exports huge quantities of grain, chiefly wheat, derived from heavily infected localities in the Punjab at a time when the plague season is at its height, but the dry climate permits of the grain being turned out in the sun in heaps on the quays and it is the custom to export it in new gunny bags. Hence the risk of exporting plague fleas is almost eliminated. As a matter of fact the exports from this port have never been incriminated as a source of the infection.

Plague persists as a smouldering enzootic at Singapore, Saigon, Bangkok, and such Dutch East Indian ports as Surabaya and Semerang. Singapore reports only four human cases in 1927. Hong Kong has given a negative report for both human and rat plague since 1923.

Bombay and Rangoon are the external sources of plague of greatest concern to Ceylon. In a geographical sense Bombay is the more dangerous port, since the distance from Colombo to Bombay is considerably shorter, 883 miles as against 1,234 for Rangoon, and the climate during several months of the year (December to March) is more favourable to the transfer of fleas and there are greater opportunities for infected rats to embark on vessels direct from the quays. This danger to shipping at the Bombay docks was carefully investigated by Chitre (1930) under the Director of the Haffkine Institute, Bombay. During the three years 1918–1920 no plague was detected among many thousand rats examined from the Princes and Alexandra docks and no plague was recognized among the vessels leaving these docks on distant voyages. On the other hand Alexandra dock was the scene of a rat plague epizootic in 1918-1919; among live rats trapped the incidence was 0·01 per cent. among rats found dead 2·2 per cent., and plague was recognized on eight vessels after leaving the dock for overseas ports. Plague rats were only found in two vessels fumigated at Bombay during the period in question, both in 1919. The incidence of plague in Bombay City itself was consistently higher than in the dock zone. Figures for rat infestation by number of rats caught per 100 traps laid showed that the rat population of the dockside was considerably higher than that of the ships, that of the lighters being intermediate. It is clear that under such circumstances everything possible should be done to reduce the movements of rats from shore to ship to a minimum. Taylor and Chitre (1923) of the Haffkine Institute have devised ingenious electrical rat-guards for mooring ropes and other means of access from the quays.

It would seem that the risk of ships arriving at Colombo with rat plague on board is greater *ex* Bombay than any other Eastern port. On the other hand the amount of plague-suspect cargo landed at Colombo from Bombay is small in comparison with Rangoon. Cotton seems to be the only article requiring special notice, about 20,000 cwt. are annually imported. Judging from the Report on Eastern Port Health Organization by Norman White (1923) the risk from this source has greatly diminished of recent years owing to recent improvements in the export warehouse. In former days it seems that Bombay cotton was stored in highly rat infested and heavily plague infected godowns. Only about half the total cotton imports come from Bombay, the rest from relatively plague free sources in Madras.

Some idea of the great decline which has taken place in plague at Bombay may be gained from some figures given in the report for 1927 by the Director of the Haffkine Institute where rat examinations are carried out on a larger scale than anywhere else. Thus during the years 1902–06 there were 73,167 human deaths and 19,410 plague rats were found, 11·8 per cent. of the total examined; in 1912–16 there were 9,852 human deaths and 3·5 per cent. infected rats; in 1922–26 there were 2,600 human deaths and only 1·4 per cent. of the 1,574,863 rats examined post-mortem were found to be infected.

TABLE VI.

Rangoon.

Human Plague Deaths.—Decennium, 1918-1927, by Months.

Year.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Total.
1918	102	284	422	219	129	157	145	83	75	52	4	16	1,688
1919	46	67	161	146	32	37	99	71	64	21	13	25	782
1920	76	202	259	131	53	52	110	132	61	18	11	22	1,127
1921	51	88	158	107	46	97	214	126	122	41	24	52	1,126
1922	131	169	217	193	96	111	130	174	77	45	27	32	1,402
1923	57	120	247	163	105	137	129	103	60	20	6	12	1,159
1924	16	47	57	64	43	56	81	71	36	15	8	11	505
1925	36	49	73	96	56	59	75	80	62	19	11	4	620
1926	14	37	48	30	15	12	13	33	34	6	8	7	257
1927	18	23	9	10	13	12	22	13	9	13	13	13	168

TABLE VII.

Bombay.

Human Plague Deaths.—Decennium, 1918-1927, by Months.

Year.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Total.
1918	71	87	185	385	179	144	43	19	15	5	4	6	1,143
1919	5	11	112	256	218	41	20	19	9	6	3	2	702
1920	4	27	30	77	39	24	27	34	9	4	0	7	282
1921	5	30	132	344	185	34	18	22	22	11	2	6	811
1922	35	73	125	163	75	23	24	37	19	25	22	11	632
1923	25	95	389	424	294	33	13	16	22	12	2	4	1,329
1924	6	46	165	117	45	7	5	14	—	—	1	3	409
1925	2	8	38	48	39	19	7	9	2	1	—	1	174
1926	2	9	4	10	11	5	2	3	4	3	—	3	56
1927	2	8	17	54	73	19	16	9	4	4	—	1	207

During the last decade Rangoon usurped the position formerly held by Hong Kong and for a time by Bombay, as the port most heavily infected with bubonic plague. As already pointed out the gigantic rice trade of this port, amounting to upwards of two million tons per annum, has been implicated in the overseas spread of the infection on several occasions.

But the position appears to be changing rapidly. Taking the large ports within a week's sail of Colombo and tabulating the incidence of human plague for the decade 1918-27 the result is as follows :—

Ports.	1918.	1919.	1920.	1921.	1922.	1923.	1924.	1925.	1926.	1927.
Rangoon	1,638	782	1,127	1,126	1,402	1,159	505	620	257	168
Bombay	1,143	702	282	811	632	1,329	409	174	56	207
Calcutta	210	334	53	37	143	77	33	9	Nil.	Nil.
Singapore	176	11	61	28	39	52	20	59	7	4

The figures for Rangoon, Bombay, and Calcutta represent deaths, those from Singapore cases of human plague. More detailed particulars are given in Tables VI. and VII.

As regards the season of the year when the transference of plague infection is most to be feared, there is a considerable difference between Rangoon and Bombay (see Tables VI. and VII.). The Bombay plague season March, April, May, is better defined. Plague prevalence is greatest in Rangoon in February, March, and April, but there may be a secondary wave in June, July, and August. In both cities the disease is at a low level in the autumn. Since the Colombo plague season extends from the beginning of November to the end of February it does not fit in well with that at either Rangoon or Bombay, a circumstance which helps to explain the former immunity of Ceylon from plague and the delay in its coastal invasion by *Xenopsylla cheopis*. In considering the data for the human plague epidemic, allowance should be made for the fact that the maximum incidence of the rat epizootic takes place some weeks earlier, and it is this that really governs the chance of plague being exported. In Oriental cities human plague incidence serves as a fairly good index to the amount of rat plague in the more densely inhabited districts.

Since Burma was the original source of Ceylon plague and Rangoon rice the vehicle of the infection, the epidemiology of Burmese plague and the conditions of the rice trade between Rangoon and Colombo need particularly close consideration. In view of this and the new light recently thrown upon the situation by the results of the important rat-flea survey now being concluded in Rangoon by Lieut.-Col. C. G. Jolly, the writer was despatched on a special mission of inquiry to this port, arriving on January 26 and departing on February 6, 1931. Every facility was granted for the collection of information as to the plague position in Burma, with special reference to the part played by the rice trade in exporting the seeds of infection overseas. The writer is particularly indebted for information and assistance to Lieut.-Col. Jolly, Major Cotter, Dr. K. R. Dalal, Health Officer, Mr. J. A. Cherry, Chairman of the Port Commission, and the officers of a British firm owning some of the largest rice mills in the Rangoon district. Some of the information obtained is very briefly summarized in the succeeding sections.

Rangoon and Bassein seem to be the only ports in Burma in which plague is definitely endemic. Moulmein, where *X. astia* appears to be the predominant rat-flea, has been much less severely affected. Akyab, another *astia* port, is practically immune from plague, despite favourable climatic conditions.

The general distribution of plague in Burma is most irregular. Thus while some districts such as Moiktila and Mandalay have suffered severely, Akyab, Kyankpyu, Mergui, and Tavoy districts have remained free. The country, as a whole, appears to present unique opportunities for the scientific study of the causes underlying the uneven spread of the infection.

Plague did not reach Burma till the spring of 1905. In the first fifteen years 98,629 deaths were registered, 20 per cent. of these occurred in Rangoon and only 18 per cent. in rural districts. It is a fortunate circumstance as regards risk of exporting infection abroad in rice that plague in Burma should be an urban rather than a rural disease.

Plague in Rangoon persists throughout the year but, as in Lower Burma generally, there are spring and summer peaks of prevalence, the former usually culminating in March and the latter in July. It appears that the spring epidemic is initiated in the outskirts of the town, where the bulk of the rice mills and stores are situated, and that the summer rise is usually due to the spread of the infection to the central endemic area of the town in the vicinity of Mogul street, an area which shows many points of resemblance to the endemic plague zone in Colombo. In Upper Burma as a rule there is only a spring rise with a maximum incidence in February. The seasonal plague curve seems to exhibit the well known effect of a fall of mean temperature within the limits favourable to plague transmission by *X. cheopis*. In Rangoon and Lower Burma the monsoon rains bring about a summer fall in the mean minimum atmospheric temperature. The air in this region is never really dry enough to have much effect upon the spread of plague.

The climate of the Burma plains is not particularly favourable to plague. So far as is known the disease persists and shows periodic cool weather increments only in those regions where *X. cheopis* occurs in abundance on very numerous domestic rats. In stations such as Mandalay the single sharp cool weather epizootic evidently effects a marked reduction in the rat population since severe outbreaks tend to recur every second year. The writer is inclined to agree with the view of Col. Bisset that if the plague could be stamped out in the large towns, particularly Rangoon and Bassein, it would eventually disappear from the whole province.

Rangoon harbours a greater variety of rodents than any other Eastern port. The following table shows the general results of rodent plague examinations at the Corporation Laboratories for the last ten years :—

Year	Total rats examined.	Total found infected.	Per Cent. infected.
1921	17,936	108	0·60
1922	18,619	109	0.58
1923	17,323	120	0.69
1924	32,315	113	0·35
1925	38,734	119	0·31
1926	38,419	128	0·33
1927	45,102	90	0·19
1928	40,376	63	0·15
1929	38,060	133	0·35
1930	33,957	50	0·15

Precise records are lacking as to the distribution of plague among the five important rodent species, the indoor *R. concolor*, *R. rattus*, and *M. musculus* and the outdoor *R. norvegicus* and the mole rats, chiefly *G. bengalensis*, but there were ten cases of plague among the mole rats in 1929 and 71 among *R. concolor*, the common Burma house rat. Assuming that the proportion of rodent species examined for plague corresponds to those trapped the incidence is nearly three times greater for the house than for the mole rats.

Below are some of the survey findings for rodent and flea species distribution in the Port area for January, 1928, to January, 1929, according to figures supplied from the Harcourt Butler Institute by Major Cotter.

PORT AREA,	Total.	Per Cent.	Fleas per Rat.	*X. cheopis* Per Cent.	*X. cheopis* Index.	*X. astia* Index.
Indoor Rats.						
Rattus concolor	2,291	32·65	0·59	19·39	0·12	0·48
Rattus rattus	644	9·18	1·54	21·82	0·33	1·2
Mus musculus	976	13·91	0·31	19·67	0·06	0·25
Outdoor Rats.						
Gunomys bengalensis	2,234	31·85	5·04	2·11	0·11	4·93
Rattus norvegicus	871	12·41	5·53	3·59	0·19	5·33

The following data from the Port area show how closely the size of the flea catch is correlated with the size and weight of the various rodents trapped :—

Trapped.		Average Weight of Adult.		Fleas per Rat.
Gunomys bengalensis	...	12·31 oz.	...	4·59
Rattus norvegicus	...	9·87 oz,	...	4·99
Rattus rattus	...	3·50 oz.	...	1·60
Rattus concolor	...	1·12 oz.	...	0·56
Mus musculus	...	0·52 oz.	...	0·28

During 1929 the survey was extended from the sparsely inhabited Port area, a narrow strip of land along the Rangoon river comprising the Port Commission premises, to a central commercial area in the town and the Pazunduang suburban and rice mill areas, where plague is endemic. The general results from both districts are similar and contrast strikingly with these from the Port. The gross *X. cheopis* percentage rose from about 5 to 25 per cent. on rats of all species. As in the Port, *X. cheopis* is several times more prevalent on the indoor species of rat than on the outdoor. *R. concolor* in the central zone harboured nearly 70 per cent. *X. cheopis* as against 20 per cent. on this rat in the Port ; not more than 10 per cent. were found on outdoor species in the two town areas. The rest of the Corporation area has now been surveyed. The rat and flea species distribution is of the same order as found in the two other inhabited areas. The nett result is that the great majority of fleas found on all species of rat in the Port area are *X. astia*, while in the town itself *X. cheopis* preponderates on the domestic species of rat. There are only about 4 per cent *R. norvegicus* in the outskirts of the town as against 12 per cent. in the Port, otherwise the relative proportions of rodent species are similar.

It is the domesticated rats that commonly give rise to human bubonic plague. In fact, as Norman White has pointed out, it may happen that a heavy plague mortality among outdoor rats has little influence on the human epidemic. The returns of rat destruction and rat examination for the Port Commission premises show a marked decline in rat plague since 1924. Only one plague rat was found upon these premises in 1928-29 as against 63 for the remainder of Rangoon in 1928.

Considerable improvements have recently been carried out in Rangoon Port. In April, 1928, the Sula Pagoda and Latter Sheet wharves were completely paved in concrete and the grain stores transferred to the Pazundaung creek foreshore. This measure resulted in a drop in the number of rats caught per 100 traps laid from 36·1 to 18·8 and brought about a still greater fall in the flea counts per rat from 11·6 to 1·8. This result can be paralleled in Colombo and in some of the results of the Madras flea survey and strikingly demonstrates the advantage of *pukka* construction and reduction in available food supply in reducing rat and flea infestation.

The predominance of *astia* on the rats of the Port of Rangoon is in marked contrast with the results obtained in the corresponding area in Colombo (see Table XII.) where the *cheopis* prevalence on *R. rattus* reached 73 per cent. in 1922-24 with an *cheopis* index of 1·74.

Attention is drawn to the Chart which shows the seasonal periodicity of *X. astia* and *X. cheopis* on Rangoon rats in the central plague endemic and Port areas. None of the rodent species in the Port area showed a significant *cheopis* infestation. On the other hand the *cheopis* infestation of domestic rats in the Rangoon central plague area is relatively high throughout the year even as compared with Bombay. The periodicity curves for the Pazundaung area are somewhat similar to those for the centre.

It seems justifiable to conclude that grain and other goods for export overseas are most likely to become *cheopis* infected or plague infected when passing through the magazines of the central endemic plague area of Rangoon or the rice mills and stores on the banks of the creeks before being lightered direct to ships in the river. Transit through the sheds and quays of the Port Commission is relatively safe in this respect.

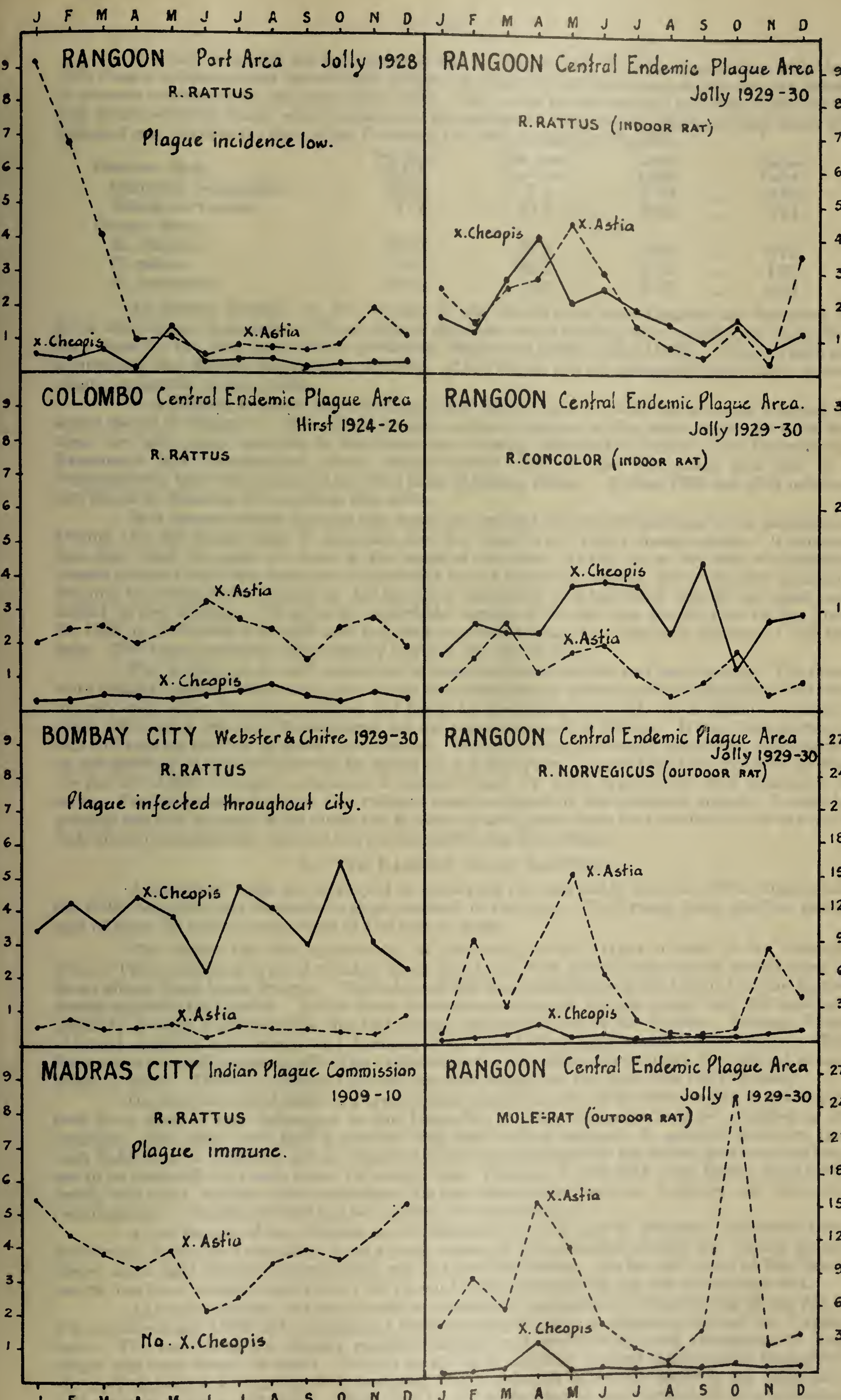
The links in the direct chain of infection between a rice mill or store in Burma through Colombo to a boutique in Kandy will now be considered in detail. Most of the rice stores in question lie on the banks of small tributaries of the Rangoon river. The rice exports are loaded in lighters alongside the mill and ferried out to ships anchored out in the main stream. The links then are as follows : export mill—lighter (Rangoon river)—ship—lighter (Colombo)—Customs import warehouses—Chalmers Granaries—inwards railway goods shed—rice store—boutique.

2.—The Rangoon Grain Export Mills and Stores.

Col. Bisset, late Director of Public Health, in his memorandum on Plague in Burma wrote as follows :—"In a plague ridden town like Rangoon the rat-proofing of rice mills is one of the most obvious measures to take. There is little doubt in view of the amount of grain a rat eats and destroys in a year that any such measure would recompense the millers merely as a matter of business apart from the Public Health argument."

The writer personally inspected several rice mills and stores in the Kemmendine quarter and in the Pazundaung creek at Rangoon as well as similar mills at Mandalay. Everywhere there was conspicuous evidence of an extraordinary high degree of rat infestation. The situation, however, is not quite so bad as it appears at first sight. The burrows that surround every rice store appear to be mainly the work of the mole rat *Gunomys bengalensis*. As already pointed out, *X. astia*, a relatively poor carrier of plague, greatly predominates on this genus of rodent both at Rangoon and Bombay and there is evidence that plague infection is relatively infrequent among the mole rats of Rangoon. The epidemiological importance of this large element of the mill rat population may, therefore, be discounted to some extent. The species, however, is susceptible to plague and in the spring season the *astia* index may reach a very high figure, quite compatible with the independent spread of plague by this flea.

SEASONAL PERIODICITY OF SPECIFIC RAT FLEA INDICES IN EASTERN PORTS



Rangoon data obtained from Harcourt Butler Institute.
Molerat roughly three times the weight of R. Rattus.
R. Norvegicus " " " " " " "
R. Concolor " one third " " " "

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It would seem that the fluctuations in the *R. concolor* and *R. rattus* population with their high *cheopis* infestation and known high liability to plague would be of greatest account *qua* danger to overseas consumers of rice from these mills. The writer is indebted to Lieut.-Col. Jolly for the data in the schedule below which summarize the surveys of rice mills in Rangoon, east town, and west and east suburbs for the period February 15, 1930, to January 20, 1931.

	Per Cent. of 514.	Per Cent. *X. cheopis*.	*astia* Index.	*cheopis* Index.
Outdoor Rats.				
Gunomys bengalensis ...	20·82 ...	7·7 ...	5·70 ...	0·48
Rattus norvegicus ...	3·31 ...	23·9 ...	3·00 ...	0·94
Indoor Rats.				
R. concolor ...	49·61 ...	76·3 ...	0·22 ...	0·71
R. rattus ...	5.25 ...	64·4 ...	1·07 ...	1·96
M. musculus ...	20·82 ...	58.9 ...	0.22 ...	0.33

As already pointed out 81 per cent. of the rice exports from Rangoon are lightered to ships direct from these mills. These figures therefore are of much greater significance to Ceylon than those for the Port zone already published, Bilderbeck (1929), Jolly (1930). Given a high rat population, the figures for *cheopis* infestation of the indoor rats are compatible with fairly severe plague epizootics in these mills.

It is difficult to assess the actual incidence of rat plague in these mills during a period of active spread in Rangoon. The spring human epidemic begins in the areas round the mills but there are not many quarters in the immediate vicinity inhabited at night. The Pazundaung, Kanaungto, and Kemmendine areas, which contain most of the rice mills, give rise to a comparatively large proportion of the total cases of human plague. During 1928 out of 63 infected rats found in Rangoon 3 were from rice mills.

It is almost certain that the rice stores are subject to great fluctuations in rat population. During the dry season there is abundant food for them in the paddy heaps outside. It appears that they tend to enter the store at the onset of the rains. If this be so the risk of exporting *cheopis* infested rice from Rangoon mills should be at a maximum during the south-west monsoon. Happily the winter rice crop is by far the most important, it is harvested and for the most part milled in dry weather. Thus for an exportable surplus of the rice crop for the year ending June 30, 1930, of 3,050,000, 2,380,592 tons had been exported by that date leaving a balance of 669,408 tons. The heavy monsoon rains usually begin at the end of May.

The writer saw no mill where any attempt had been made at real rat-proofing. The floors were usually covered with one or two layers of matting which affords a serious obstacle to burrowing rats only when in good condition but has to be frequently renewed. It is difficult to understand why *pucca* rat-proof foundations are not more employed in Burma. It has been estimated that 375 rats eat one ton of grain per annum. Under average economic conditions expenditure on rat-proofing of rice mills should be recouped in a few years. Lieut.-Col. Jolly informs me that the justice of this economic argument is acknowledged by some experienced local managers of mills. For the present it seems that reliance must be placed in the economic appeal. It may be pointed out that in some mills much use is made of new gunny bags for rice about to be exported. This should considerably reduce the risk of transferring fleas abroad.

3.—The Rangoon Grain Lighters.

A variety of boats are employed in conveying rice and paddy from the Delta district and the mills on creek and riverside to ships moored in the river. They range from shallow paddy gigs of some 30 tons to cargo boats of 120 tons or more.

The writer had the opportunity of inspecting several types of craft in the Rangoon river. The commonest type of wooden cargo boat lined with boards over its ribs would seem to be an almost ideal home for rats. The debris of rice penetrates between the boards into the hollow spaces available for nesting. Under these circumstances figures for rats caught per 100 traps laid probably greatly underestimate the real average rat population of the lighters. Norman White obtained eighteen rats from a trial fumigation of one of these lighters selected at random. The Rangoon river trade seems to afford an exception to the rule that comparatively few rats get aboard ships in cargo. There is evidence that rats are often slung into the hold with the rice bags.

On the other hand there is a type of steel lighter in use on the river which is practically free from rats. Those belonging to the Irrawaddy Flotilla Company may be specified as an example. The clean steel hold is covered with steel sliding hatches. It appears, however, that such lighters, as in Colombo, are no longer in favour since experience has shown that they are very apt to be damaged by rough usage in heavy tides. Probably a type with steel frame, steel bulkheads, and stout wooden sides represents the best compromise between hygienic and economic requirements. The ribs should not be boarded over internally.

A flea survey of the lighters on the Rangoon river is now in progress. As about 4,000 boats come down the Irrawaddy from a great extent of rice growing country the results should throw some light on the corresponding rat and flea distribution. So far the count of fleas taken per rat has been extraordinarily low ; the reason for this anomaly has not yet been discovered.

As yet no attempt has been made at systematic fumigation or rat-proofing of the 700 to 800 registered and 4,000 odd unregistered boats annually arriving at Rangoon through the Twente canal. The steel boats are already rat-proof enough and would only need fumigation if dead plague rats were found on board. As will be shown in the later sections of this report fumigation of empty lighters is a very simple procedure. At Colombo all lighters in harbour are fumigated with sulphur once a fortnight. There can be no doubt that if the formidable administrative difficulties could be overcome the systematic fumigation of the wooden river craft of Rangoon engaged in the rice trade with either cyanide or sulphur would be a valuable international safeguard against the spread of plague. Norman White (1923) in his report to the Health Section of the League of Nations, expressed the opinion that this measure is essential. If the work cannot be done by the Port Health Authority it might possibly be undertaken by a fumigation company under official supervision.

Even in the absence of rats and fleas belonging to the lighter itself plague could be readily transferred from the mills to the ships in the bodies of fleas. On the death of rats in the mill their fleas would tend to wander at random over the produce adjacent and take refuge in the interstices of the gunny bags in the manner described in the preceding section. The same sequence follows the occurrence of rat plague among the lighter rat population, but in this event the chance of directly embarking a live plague rat must be decidedly greater.

If a rice mill is known to be infected with plague the best method of securing the safety of its rice exports would be fumigation with cyanide in the lighter after the manner described in a later section of this report.

4.—Grain Ships on Eastern Routes.

The transference of infected fleas all the way from Rangoon to Colombo without their feeding on ship rats *en route* is theoretically possible, but the sea voyage is about two days too long to favour this mode of spread. For long distance voyages the dictum holds good that if vessels are kept free from rats they will not carry plague. The voyage between Rangoon and Colombo is a border line case.

It is highly improbable that an infected rat could be shipped at Rangoon, reach the quay-side at Colombo, and survive to spread the infection ashore. The greatest risk is the occurrence of an epizootic among the ship's rats as a result of embarking plague fleas at Rangoon. It seems probable that both Nagapatam and Colombo were infected in this way by the same ship bringing rice from Rangoon at the end of 1913. This involves the consideration of the rat and flea state of the ships engaged in the grain trade between Rangoon and Colombo.

The prevalence of rats on ships from all ports of the world has recently been investigated elaborately by the Quarantine authorities at New York and the results are reported by Williams (1929). The outstanding features are "that the majority of the rats are carried by relatively few ships and that conversely the majority of ships carry few rats, only about 10 per cent. of the ships arriving at New York are heavily rat infested (over 30 rats) and these are the potentially dangerous vessels."

Heavily rat infested ships usually remain in this condition despite repeated fumigation ; such ships are always found on inspection to have extensive and remote rat harbourages where the rats are able to entrench themselves against all attacks.

The American authorities have devoted much attention to this vitally important question of the rat-proofing of vessels and the elimination of the above-mentioned rat harbours. A number of the largest vessels afloat have already been dealt with on the lines worked out in the memorandum on rat-proofing of vessels (Grubbs and Holsendorf, 1925). Ships have remained entirely free from every sign of rat infestation for more than a year after being rat-proofed at New York. The specifications and administrative details are given in the report. Even if rat-proofing does not ent ·ely eliminate rats it will render fumigation effective and so bring the rat population under control.

Vessels entering dock from Eastern ports are fumigated at Colombo, but systematic examination of the rat carcases has only recently been undertaken, so far with negative results. Consequently no accurate information is available regarding rat infestation of vessels putting in to Colombo or the frequency of epizootic plague on board ships in the harbour.

No human cases of plague have been taken off ships in harbour for the last seven years. The medical inspection of crew or passengers on board incoming vessels, however, affords no adequate criterion of the plague state of the ship. Severe epizootics of rat plague have been found on vessels on which no human cases occurred.

Perhaps the most instructive data as regards rat plague on shipboard are those contained in the recent service publication by Cumpston and McCallum on The History of Plague in Australia.

The following is quoted from page 205 :—" The experience of the 1908 to 1909 and 1921 to 1922 years of plague indicates that in no instance was the presence of a single infected rat, or the transmission of infection by a single infected rat suspected or proven. In every case plague on shipboard was in epizootic form, multiple rodents being identified. This would suggest that the single infected rat is not an epidemic factor of material importance except as an initial focus for a definite ship-epizootic, whilst this experience indicates as an important control measure, the frequent deratisation of vessels to keep the rodent population below numerical level of epizootic density."

A rat-flea survey of grain ships in Colombo harbour was instituted in August, 1928. Wonder wire traps have been systematically laid as opportunity afforded in the holds or superstructure after discharge of grain. The results so far obtained are shown in Table VIII. 133 ships have yielded 737 rats of all species and 1,743 fleas of which 95·1 per cent. were *X. cheopis* and only 4·9 per cent. *X. astia.* No other species were found. These figures are of particular interest since they show a much higher proportion of *X. cheopis*, the most dangerous plague carrying species, than has so far been recorded from any Indian port touched by the ships surveyed. Thus the results are in striking contrast with those obtained recently at the port of Rangoon. Only three vessels from Rangoon show a preponderance of *X. astia*, all in May, 1929. Taking the gross results for Rangoon as a whole 87 vessels yielded 461 rats and 975 fleas, of which 60 or 6·2 per cent. were *X. astia* and the rest *X. cheopis.*

The first ship flea surveys ever made were those reported by Gauthier and Raybaud from Marseilles (1910). Among 2,276 fleas from ships in the harbour 92·7 per cent. were *X. cheopis*, 6·7 cent. *C. fasciatus*, 0·5 per cent. *L. musculi*, and 0.8 per cent. *P. irritans.* Similar results have been reported from Hamburg, Liverpool, Odessa, and Yokohama. Williams (1929) reports the results of the identification of the fleas taken off fumigated rats at New York Quarantine Station. A great preponderance of *X. cheopis* was found in all routes except one, the direct route between New York and the ports of North Europe, here *Ceratophyllus fasciatus* is the predominant flea. It may be pointed out that the writer drew attention in 1924 to the remarkable freedom of this sea-route from plague despite an immense traffic in grain, attributing it to the relative inferiority of *C. fasciatus* as a vector of plague.

It seems clear that the conditions on shipboard along tropical and sub-tropical routes are specially favourable to the preponderance of *the* plague flea, *X. cheopis*. It will appear from what follows that of all the links in the chain of infection between Rangoon and Colombo that of the ships is the strongest *qua* the flea species factor. Whether the increase in *X. cheopis* which occurs on grain ships *en route* to Colombo is relative or absolute will depend entirely on the degree of rat infestation. As will be explained later the total flea population of a given species infesting any particular premises is a function of both the rat population and the average number of fleas borne by each rat. Other factors being equal, the intensity of a rat-epizootic on shipboard or in any other type of premises will be governed by the size of the flea population.

The result of these rat-flea surveys of ships travelling along tropical routes strengthens the case for the systematic deratisation of vessels, the measure on which so much stress is laid by the Dutch, Australian, and American authorities.

TABLE VIII.

Rat-flea Survey of Grain Ships in Colombo Harbour.—October 1, 1928–September 30, 1929.

Rattus rattus.

Source of Cargo.	No. of Ships trapped.	No. of Ships yielding *R. rattus*.	No. of *R. rattus* searched.	No. of Fleas found.	No. of *X. astia*.	No. of *X. cheopis*.	Per Cent. *X. cheopis*.	*Cheopis* Index.
Rangoon ...	87	29	108	296	14	282	95·27	2·61
Bombay ...	22	11	12	16	4	12	75·00	1·00
Calcutta ...	17	5	48	86	1	85	98·84	1·77
Singapore ...	7	1	2	37	—	37	100·00	—
Total ...	133	46	170	435	19	416	95·63	2·45

Rattus norvegicus.

		No. of Ships yielding *R. norvegicus*.	No. of *R norvegicus* searched.	No. of Fleas found.	No. of *X. astia*.	No. of *X. cheopis*.	Per Cent. *X. cheopis*.	*Cheopis* Index.
Rangoon ...	87	74	353	679	46	633	93·24	1·79
Bombay ...	22	13	116	467	3	464	99·4	4·02
Calcutta ...	17	17	66	127	17	110	86·61	1·66
Singapore ...	7	6	32	35	—	35	100·00	1·09
Total ...	133	110	567	1,308	66	1,242	94·95	2·18

Three ships from Rangoon yielded 4 mice bearing 6 *X. astia* and 6 *X. cheopis*.

5.—Lighters in Colombo Harbour.

The rat infestation of the 709 lighters is kept down by means of fortnightly fumigations with sulphur dioxide. The few rats now found after these fumigations are divided about equally as regards species between *R. norvegicus* and *R. rattus kandianus*. Black rats, such as are common on ships in the harbour, are rarely seen in the lighters. It is clear that the vast majority of the rats of the lighters are of local origin, they form a part of the shore rat population and are not derived from the ships.

On reference to Table X. it will be noted that five cases of rat plague have been detected on lighters since 1920, and that in each case the species was *R. rattus kandianus*, the local species. In some instances these rats may have caught their infection on shore, but the 1926 plague rat found in a grain lighter was the first of a new series. Its occurrence preceded an outbreak of plague in the Granaries and a recrudescence of the disease in Colombo itself. It seems clear in this instance that the rat—an indigenous species—must have been infected through imported plague fleas transferred to it from produce loaded into the lighter. As already indicated the vehicle of the infection between the ship and the lighter is much more likely to be the flea than the rat: the above instance illustrates the point.

Eight cases of human plague are registered as occurring among boatmen in harbour, but the true incidence may be much greater. It is difficult to decide to what extent a particular case of plague is occupational in view of the fact that so many of the harbour employees live close to their work in or about the endemic plague area adjacent.

6.—The Port Commission Premises.

The importance of rat-proofing quayside warehouses, as far as is humanly possible, is universally recognized. Structural improvements designed to eliminate shelter for rats should be supplemented by a continuous rat destruction campaign. This is the policy pursued in Colombo, but despite every effort, including the employment of rat-catching gangs and the construction of a number of modernized rat-free warehouses, the rat population is still fairly large and definite plague epizootics occurred in 1914, 1918, 1921, and 1923. See Tables X. and XI. for an analysis of the distribution of rat plague in the Customs premises and Government Granaries. It will be noted that, except in 1914, much the heaviest incidence has fallen on the import side of the harbour. The export side adjoins the endemic plague area and the sporadic rat plague which has occurred there may merely represent an extension of the town epizootic into the harbour zone.

The Customs premises are guarded by a high wall with gates at wide intervals for passage of traffic by road or rail. It would be advantageous to render this wall and all entrances as rat-proof as possible, paying special attention to those premises facing Reclamation road, Seashore street, and Kochchikadde, which forms part of the endemic plague area. All gates should be rat-proofed and closed as soon as possible after dusk.

Another point bearing on the exchange of rats between the harbour and the endemic plague area may be mentioned here. Underlying the Pettah and nearly all those adjoining streets where plague tends to persist, despite the vigorous measures directed against it, is an old system of underground drains which discharge into the harbour above sea level. When these drains are suddenly flooded by heavy rains rats are washed out of their mouths into the harbour. The writer has recently been informed on good authority that some of these rats have been observed to swim out to a buoy, dry themselves on it, and then ascend mooring ropes to a ship in the harbour. It will be realized that since these rats are more liable to be infected with plague than those of any other locality in Ceylon all such means of access to shipping should be cut off. The solution of the problem, however, is fraught with some difficulty. It is impracticable to screen off the ends of the drains. The exits are now being brought well below sea level.

Attention is once more drawn to the very heavy *X. cheopis* infestation of the rats of the Customs premises. In 1928 the *cheopis* index for these premises, 2·30, was the highest so far recorded anywhere in Ceylon save the commercial part of the plague area of Kandy. It is more than twice as high as that of the endemic plague area, Colombo.

TABLE IX.

Distribution of Cases of Human Plague noted in Plague Register as employed in Colombo Harbour or in handling Imported Grain.

1914–1927.

Colombo Harbour.	1914.	1915.	1916.	1917.	1918.	1919.	1920.	1921.	1922.	1923.	1924.	1925.	1926.	1927.	Total
Loading Wharf and Coal Coolies	15	9	6	3	4	13	9	2	2	4	2	5	—	2	76
Boatmen	3	1	1	—	—	—	1	—	1	1	—	—	—	—	8
Grain dealers and coolies handling rice bags ...	4	4	—	3	—	—	3	1	7	7	2	—	1	7	39
	22	14	7	6	4	13	13	3	10	12	4	5	1	9	123

2,299 human cases of plague were recorded from all parts of Colombo during this period.

TABLE X.

Distribution of Plague Infected Rodents found in Premises adjoining Colombo Harbour and Government Granaries.

1914–1927.

	Rattus rattus.	*Rattus norvegicus.*	*Bandicota malabarica.*	*Mus dubius.*	Total.
Colombo Harbour.					
1. South-west Breakwater to Canal	57	6	1	Nil	64
2. Canal to Block-loading Jetty	10	5	2	Nil	17
3. Block-loading Jetty to North-east Breakwater ...	12	19	Nil	Nil	31
4. Lighters and Boatsheds	5	Nil	Nil	Nil	5
Government Granaries.					
1. Chalmers Granaries	10	3	Nil	1	14
2. Manning Markets	6	5	Nil	Nil	11

The total of 117 plague rodents found in the Harbour premises forms 10·4 per cent. of the total 1,124 found in the whole city during the same period.

TABLE XI.

Annual Distribution of Infected Rodents.—Colombo Port and Import Granaries.

	1914.	1915.	1916.	1917.	1918.	1919.	1920.	1921.	1922.	1923.	1924.	1925.	1926.	1927.	Total
Colombo Harbour.															
1. South-west Breakwater to Canal, Import side	4	Nil	Nil	Nil	17	Nil	2	12	2	27	Nil	Nil	Nil	Nil	64
2. Canal to North-east Breakwater, Export side	15	5	1	Nil	3	4	8	5	2	1	Nil	Nil	1	3	48
3. Lighters and Boatsheds ...	—	—	—	—	—	—	1	—	—	—	1	—	1	2	5
Government Granaries.															
1. Chalmers Granaries ...	—	—	—	—	—	Nil	3	1	Nil	Nil	1	2	Nil	7	14
2. Manning Markets	—	—	—	—	—	5	3	Nil	1	Nil	2	Nil	Nil	Nil	11

Systematic trapping of the Chalmers Granaries, Manning Markets, and Lighters in Harbour did not commence till 1919.

TABLE XII.

Rat-flea State of H. M. Customs.

	Rats searched.	Fleas taken.	*X. astia* Per Cent.	*X. cheopis* Per Cent.	*X. cheopis* Index.
1922-24 ...	219 ...	523 ...	27·0 ...	73·0 ...	1·74
1928 ...	372 ...	1,524 ...	43·1 ...	56·8 ...	2·30

TABLE XIII.

Results of Systematic Rat Destruction.—H. M. Customs.

Year.	Average No. of Traps laid per day.	No. of Rats caught.
1920 ...	... 133 ...	... 2,507
1921 ...	... 238 ...	... 2,483
1922 ...	... Not available ...	... 2,491
1923 ...	... 171 ...	... 1,953
1924 ...	... 141 ...	... 1,761
1925 ...	... 102 ...	... 1,545

7.—Chalmers Granaries and Manning Markets.

These stores were constructed by Government with the primary object of preventing the carriage of plague to the up-country districts, where the climate is favourable to serious outbreaks, through the medium of the huge quantities of rice formerly stored in privately owned godowns. They are supervised by officials of the Board of Immigration and Quarantine. The individual stores are leased out to the wholesale dealers in rice who formerly occupied the rat-ridden *X. cheopis* infested premises in the vicinity of Sea street, where plague first broke out and where it is still endemic.

Unfortunately, though a vast improvement on the old stores, the construction of the Government Granaries is not in accordance with modern conceptions of efficient rat-proofing. In fact they do not comply with the amended grain regulations passed in 1925 under the Quarantine and Prevention of Diseases Ordinance (1897).

The essentials of the ideal wholesale rat-proof grain store are as follows :—

(1) It should be rain-proof and dry. There should be no water within accessible to rats. Nothing but dry grain should be kept in it. Rats cannot breed without water. If introduced with grain into a really dry store they must soon leave.

(2) The store should be built on a three-foot high vertical plinth with a smooth surface all round. On the side containing the entrance there should be projecting ledge to the plinth nine inches wide, or the plinth on this side may be extended out as a platform a few feet wide guarded with a nine-inch projection. Such a platform would facilitate loading direct from railway wagons or carts. No steps to the platform should be allowed. No rat could enter a store of this type except it was carried in amongst the goods and then it would soon have to leave. There need be none of the expensive double handling of rice bags involved in designs depending on rat-proof barriers opposite doors at ground level.

(3) The foundations, wall, and roof, should be of rat-proof material.

The reconstruction of the granaries to conform to (2) seems practicable at no great expense by simply widening and deepening the drains. At present rats can get in and out through the doors and there is water available in the open drains immediately outside the granaries. It should be easy to keep the rat population of the granaries below the level at which rat epizootics can occur and to limit the spread of infection introduced into any one compartment of a granary to that compartment alone. With these objects in view improvements to the granaries were carried out in 1928. A red line was carried three feet from the top of the walls which was to serve as a limit to the piling of rice bags. Above this line the rough walls of concrete were smoothed with cement. Formerly on emptying a particular compartment to get at the rats concealed behind rice bags, the rat colony dashed for the corners and made a vertical and rapid ascent of the concrete partition walls to the compartments adjoining; the sole result of attempts at destruction was to chase the rats, and any infection they might happen to harbour, all over the granary.

It is now possible to carry out a quarterly deratisation of each compartment in series, since when the rice bags are cleared and the improved doors shut the rats can no longer escape the rat-killing coolies.

The doors are now thoroughly rat-proof. It is hoped that if they are shut in the evening as soon as the turmoil of traffic is over, but few rats will get in. Much will depend on close supervision and the goodwill of the lessees whose interest it is to keep down the rats. The writer has been recently assured by the custodian of the compartments occupied by a well known firm of rice merchants that rats have considerably diminished in numbers since the improvements were made as indicated by the greatly reduced damage to the gunny-bags.

It is important to realize that fleas cannot live long without rats and that simple storage of fleas infested produce in a rat-free granary will produce a rapid reduction in flea numbers and further that if the rat population of a granary is effectively broken up into units of not more than a few rats apiece, no severe epizootic is possible and little plague can be distributed from it.

It will be noted on reference to Table X. that 14 plague rats have been detected in the Chalmers Granaries and 11 in the Manning Markets. Table XIV. shows that the *X. cheopis* percentage and *X. cheopis* index is high. This favours infection. It is unfortunate that the Government Granaries should be so close to the Colombo endemic plague that they are liable to infection by rat migration as well as by importation from overseas.

The granaries are surrounded by a high wall and the gates, which are kept shut at nights, have been rat-proofed, but, it appears, this does not prevent rats crossing Front street when the doors are open.

No pains or reasonable expense should be spared to eliminate rats from these granaries as far as possible and to maintain a systematic and continuous campaign for the destruction of those rats, which despite all precautions, will nevertheless succeed in gaining admission to such an enormously attractive bulk of their favourite food.

TABLE XIV.

Rat-flea State of Government Granaries.

	Rats searched.	Fleas caught.	*X. astia* Per Cent.	*X. cheopis* Per Cent.	*X. cheopis* Index.
1922-24	204	347	34·9	65·1	1·11
1928	95	184	41·3	58·7	1·10

TABLE XV.

Results of Systematic Rat Destruction.—Operations at Government Granaries.

Year.	Average Number of Traps laid per Day.		Number of Rats caught.	
	Chalmers Granaries.	Manning Markets.	Chalmers Granaries.	Manning Markets.
1920	98	69	1,369	744
1921	101	69	2,524	1,769
1922		Not available.	3,268	1,255
1923	147	57	2,947	661
1924	124	48	3,274	816
1925	120	49	2,448	1,088

8.—Railway Goods Sheds.

The following figures for rice and paddy distribution by rail, 1927, were supplied by Rail Headquarters.

	Tons.
Colombo Main Station	61,204
Colombo Wharf Station	20,222
Colombo Fort (Chalmers Granaries)	77,514
Maradana Fort (Kelani Valley)	26,892

A vast quantity of goods of all kinds, including rice, is loaded in railway premises situated between the endemic plague area in Colombo and the chief sporadic zone near the Dean's road market. Nine plague rats have been found in Maradana goods yard since plague broke out in Colombo.

The outward goods sheds in the Maradana goods yard is an important link in the chain of transference of plague infection to up-country stations. This shed cannot be rat-proofed effectively as it stands. It will require to be entirely rebuilt in accordance with the specifications and plans laid down by the Committee on Rat-proofing of Railway Goods Sheds. In this instance simple "rat-free" construction will not suffice. The platform on which the shed is built should be completely protected against the ingress of rats by a three-foot smooth surround and a nine-inch projecting sill. Till this is done so long as plague remains in Colombo there will always be a danger of transfering a plague rat direct to any station on the main line. If any goods attractive to rats are kept over-night in the Maradana goods sheds they should be stored in special compartments which should be provided with rat-proof doors and should be thoroughly deratised at least four times a year.

Following the grain wagons to the Kandy inwards railway goods shed the final link is reached in the chain of infection under consideration. According to general principles of plague prevention all premises, whether publicly or privately owned, in which grain is stored over-night should be rendered as rat-free as possible and in this respect the Government Railway may be expected to set an example to the sanitary authorities of the locality, both as regards structural improvements and administrative anti-rat measures.

In the case of the Kandy inwards goods shed it would be advantageous to provide the platform with a rat-proof sill and smooth the surround between this sill and earth to prevent egress of rats from the yard. There have been two outbreaks of rat plague in Kandy already, so there is always the possibility that the store may be infected from Kandy itself. The compartment reserved for grain should be cleared at least once a quarter so that any introduced rats may be got at and killed.

The danger of transfering plague to Kandy by rail, however, depends much more on the state of the outwards railway goods shed at Colombo than on that of the inwards shed at Kandy.

III.—Internal Foci of Plague Infection.

1.—Historical Note on the Transference of Plague Infection to Ceylon.

From the end of the 17th to near the end of the 19th century plague smouldered in endemic foci in China, Arabia, and Central Africa. The present pandemic of plague originated in the mountain valleys of Yunnan, reached Canton and Hong Kong in 1894 and Bombay in 1896.

The extension of this pandemic, the fourth of the Christian era, has been altogether unprecedented, no doubt as a conseqence of the great development in means of transport and lines of communication during the 19th century. Many islands, including Formosa (1896), Madagascar (1898), Java (1911), and Ceylon (1914), were infected for the first time. The disease also obtained a footing on the coast line of the American and Australian continents. During the years 1898-1901 plague spread rapidly over the northern plains of India which became the scene of exceptionally severe epidemics. Within twenty years upwards of ten million deaths occurred in the Punjab, United Provinces, and the adjacent tracts of Bombay and Bengal. Plague spread very unequally over India and on the whole very slowly towards the south. Large tracts of territory in Madras, Burma, and Bengal have remained comparatively unaffected up to the present time.

Eventually, in November 1913, plague broke out at Nagapatam, a port in southernmost India, only 480 miles by sea from Colombo. Late in December, 1913, large consignments of rice reached Colombo *viâ* Nagapatam, where the epidemic was then at its height. There can be no reasonable doubt that this rice was the vehicle by means of which plague infection was first transferred to Colombo. The first rat and human cases occurred in premises in Sea street where this rice was stored. Plague is not endemic at Nagapatam. Rangoon was the ultimate source of this rice, and probably also of the associated infection.

During 1918 and 1919 there was a marked decline in plague incidence in Colombo. Only one case of plague was reported in February, 1919, and three in March, while the preceding January and the succeeding months of April, May, June, and July were entirely free of both rat and human plague. Unfortunately, about June, 1919, the overseas supplies of rice began to fall short, and the dealers imported increasingly large amounts of grains other than rice as a substitute for it. Rice is the only cereal stored in the Government Granaries. Thus an undue proportion of the food imports of the whole Island came to be concentrated in the godowns of the Pettah, Sea street, and market areas. This resulted in a sharp recrudescence of plague due either to a re-importation of the infection from overseas or to a revival of a smouldering enzootic of rat plague following upon the unrestricted multiplication of rats and fleas in these unprotected stores.

In 1925 human plague declined to 64 cases, the lowest annual figure recorded since it first appeared. During the first six months of 1926 there were only six human cases and despite an intensified search no rat plague was discovered in any part of the town between February 19 and September 3. A plague rat was then found in a grain barge in the harbour, another in the Customs Warehouse, and three others in premises near the harbour, while in January and February, 1927, out of 19 plague rats one was in a grain barge, one in the Customs Warehouse, four in the Chalmers Granaries, five in private grain stores supplied from the Government Granaries, three in premises adjoining such stores, and the remaining five in premises in the neighbourhood. From these foci the disease was once more re-established in Colombo, in this instance almost certainly as a consequence of re-importation of the infection from overseas.

2.—Plague and the Grain Trade in Colombo.

In Colombo there is a three-fold relationship between the distribution of plague, of imported grain, and of the imported rat-flea, *Xenopsylla cheopis*. This is shown in the diagram.

As is now well known, both the distribution of plague and that of *X. cheopis* in Colombo are very irregular. Plague is endemic in the zone defined in the succeeding section. It frequently breaks out in the neighbourhood of the markets at Dean's road and Nagalagam street and cases are not infrequent in San Sebastian and Slave Island. Elsewhere only occasional sporadic cases occur.

The wholesale stores containing the bulk of the grains other than rice imported to Ceylon are situated in Fourth Cross street and Bankshall street, Pettah. There is also much grain in Fifth Cross street adjoining, while the wholesale rice trade was formerly centred round Sea street, St. Paul's. A large trade is carried on in all kinds of grain in the vicinity of Dean's road and Nagalagam street markets. Numerous small boutiques keeping a few bags of grains are scattered throughout the populous parts of the city. Now in the 1922-24 rat-flea survey of Colombo the rats of Fourth Cross street yielded 45·6 per cent. *X. cheopis*, those of Sea street, St. Paul's, 23·6 per cent., the Dean's road market area 8·75 per cent., and that of Nagalagam street 7·04 per cent. During the 1928-29 survey corresponding figures for the *X. cheopis* infestation of Sea street were 25·2 per cent., Fourth Cross street 29·7 per cent., and Bankshall street 36·2 per cent., the two market areas, however, only showed 2·56 per cent.

On the other hand *X. cheopis* is rarely found on the rats of purely domestic premises. Thus 167 streets surveyed during the 1922-24 plague seasons showed no *X. cheopis* at all.

If the city is divided into districts as self-contained as possible as regards rat migration, as the writer has done in his published reports, it is found that the co-efficient of correlation between human plague incidence and *cheopis* prevalence is remarkably high whatever criterion for rat-flea prevalence is employed, even when the figures are weighted to compensate for possible inaccuracies in the data.

The spread of plague in the city is not, of course, governed exclusively by the flea species factor. Even if the percentage of *X. cheopis* on the rats were as high as 100 and the *X. cheopis* index—average number of *X. cheopis* per rat—as high as 3, there would be little plague if rats were scarce in the granaries. The number of fleas capable of taking part in plague transmission in any given premises clearly depends upon the number of rats. No rats—no fleas—no plague.

The total flea population of a granary is given by the number of rats in the granary × the average number of fleas per rat × a factor which depends on the proportion of the total flea population of the species of flea normally living on the body of the rat.

In addition to the number and species of rats and their susceptibility to plague infection which in Colombo is everywhere high, and the number and species of rat-fleas, there is the factor of climate; *X. cheopis*, the most efficient plague carrying flea, will not transmit plague to any extent if the temperature is too hot or too cold to favour its activities; thus there is seldom much bubonic rat plague in Colombo, or anywhere else, during periods when the mean temperature exceeds 80°F., as it does in low-country Ceylon for many months of the year. In some parts of Ceylon, *e.g.*, the Northern and North-eastern provinces during the hot weather, the dryness of the atmosphere is unfavourable to the survival of plague fleas. Heat and dryness not only impair the transmitting power of the individual rat-flea, but they slow down flea reproduction and lower the average number of fleas per rat. The violent seasonal oscillations in plague in North India follow the correspondingly violent fluctuations in climatic conditions and flea numbers. On the other hand in stations such as Kandy, the climate is such that plague might spread at almost any time of the year. There are, therefore, four factors governing the probabilities of plague breaking out in a particular grain store at any particular time, the rat population, the rat-flea population, the climatic conditions, and the communication factor, *i.e.*, frequency of introduction of plague rats and fleas from elsewhere.

The storage of grain in Colombo city is controlled under regulations passed under the Quarantine and Prevention of Diseases Ordinance, 1897, under which premises where grain is permitted to be stored are divided into three categories. "Grain stores"—allowed more than 50 bags; "grain shops"—allowed not more than 50 bags; and "grain boutiques"—allowed not more than 5 bags. The structural requirements for each type of premises laid down in the Grain Regulations increase in stringency in proportion to the amount of grain allowed.

In the Pettah district there are 90 premises where more than 100 bags of grain or forage could be stored, 36 of these are situated in Fourth Cross street and 26 in Fifth Cross street, *i.e.*, the streets showing the highest proportion of *X. cheopis* on rats. Nine are situated in St. John's road, 6 in Bankshall street, 4 in Keyzer street, 4 in Norris road, 2 in Maliban street, and 2 in Main street, all heavily *X. cheopis* infested streets. In St. Paul's Ward adjoining there are 14 such premises, in Nagalagam street (market area) 13, in Dean's road (market area) 4, in Slave Island 6, in St. Joseph's Street 2, and 2 more only in the whole of the rest of the city.

3.—The Endemic Plague Zone of Colombo.

Gazette No. 7,214 of September 30, 1921, declared an area comprised between St. John's road, Fish Market Kochchikadde, Hulftsdorp, and Kayman's gate a "diseased locality" wherein special anti-plague regulations could be enforced. The boundaries of this locality appear to have been fixed on the basis of the gross number of human plague cases occurring since the disease broke out. If, however, the human plague case incidence be calculated on the basis of the population, as per Census of 1921, in the Census blocks of the Pettah, St. Paul's, and San Sebastian districts, as has been done by the Director of Statistics, the outline of the area of highest human plague incidence assumes a somewhat different form and then corresponds with remarkable accuracy with the zone of maximum infestation of rats with the rat-flea, *Xenopsylla cheopis*.

The writer would define the "endemic plague area" as the Pettah district lying between First and Fifth Cross streets together with a northern extension along the Harbour front including Seashore street, Sea street, Chekku street, and the blocks adjoining, as far as Jampettah street.

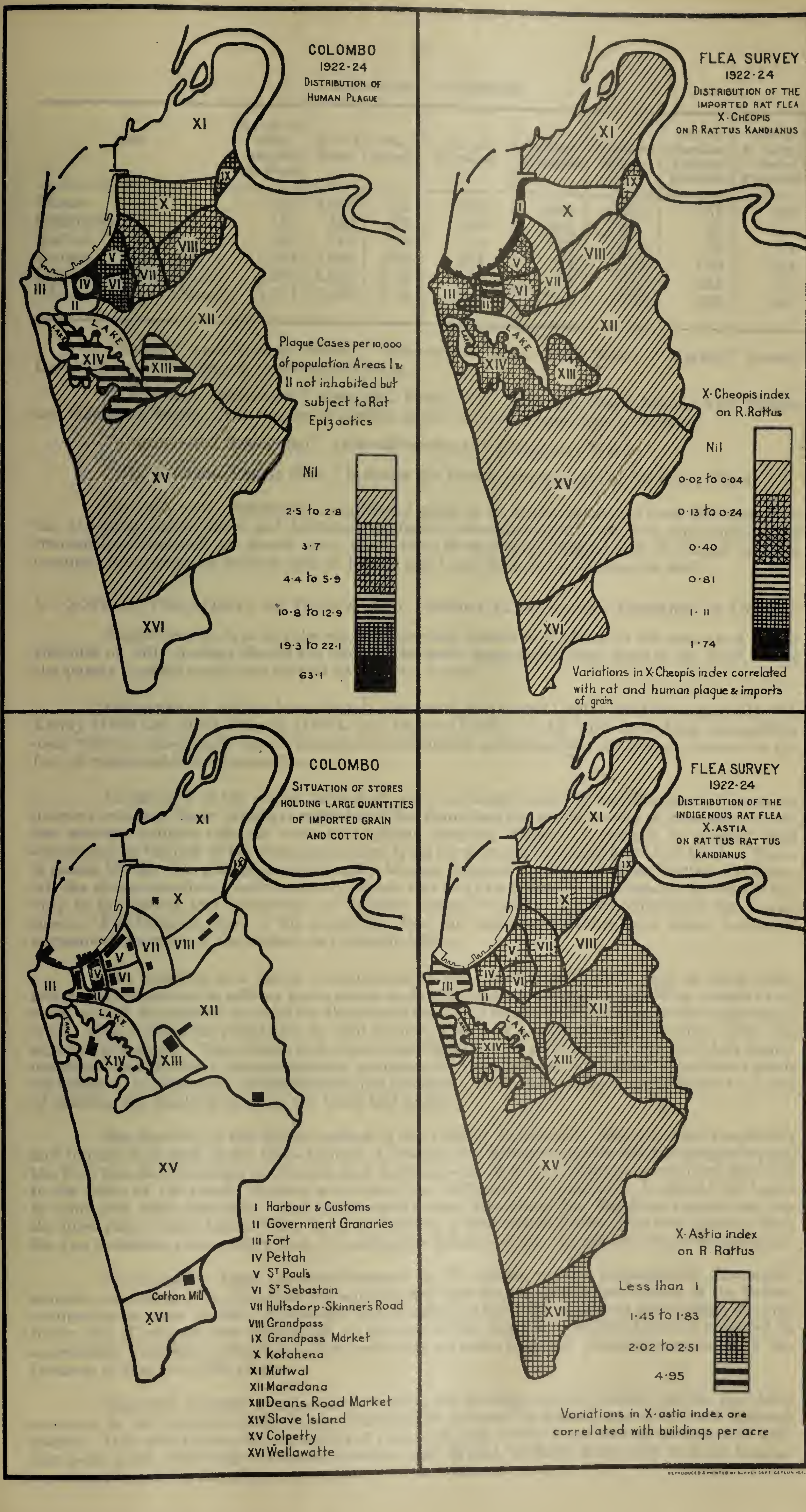
Next to the Customs premises and Government granaries, the "endemic area", particularly that part of it adjoining Bankshall street, St. John's road, and Fourth and Fifth Cross streets, Pettah, is the chief grain distributing centre in Ceylon.

TABLE XVI.

Results of Rat-flea Surveys of Colombo City by Nature of Premises Trapped.

1922–1924. Plague Season only.

Area.	No. of *R. rattus* searched for Fleas.	No. of Fleas.	Flea Index.	No. of *X. cheopis*.	Per Cent. *X. cheopis*.	*X. cheopis* Index.	No. of Premises Yielding Rat-fleas.	No of *X. cheopis* Infested Premises.
Bazaar ...	270	965	3·57	276	28·60	1·02	117	61
Commercial ...	67	348	5·19	16	4·59	0·24	34	5
Market ...	221	669	3·03	56	8·37	0·25	88	22
Congested Residential ...	1,556	4,953	3·18	257	5·19	0·17	625	74
Uncongested Residential..	1,053	2,987	2·83	35	1·17	0·03	490	15


COLOMBO
1922-24
Distribution of Human Plague
Plague Cases per 10,000 of population Areas I & II not inhabited but subject to Rat Epizootics
Nil
2·5 to 2·8
3·7
4·4 to 5·9
10·8 to 12·9
19·3 to 22·1
63·1
FLEA SURVEY
1922-24
Distribution of the imported rat flea X. Cheopis on R. Rattus Kandianus
X. Cheopis index on R. Rattus
Nil
0·02 to 0·04
0·13 to 0·24
0·40
0·81
1·11
1·74
Variations in X. Cheopis index correlated with rat and human plague & imports of grain
COLOMBO
Situation of stores holding large quantities of imported grain and cotton
Cotton Mill
I Harbour & Customs
II Government Granaries
III Fort
IV Pettah
V St Pauls
VI St Sebastain
VII Hultsdorp-Skinner's Road
VIII Grandpass
IX Grandpass Market
X Kotahena
XI Mutwal
XII Maradana
XIII Deans Road Market
XIV Slave Island
XV Colpetty
XVI Wellawatte
FLEA SURVEY
1922-24
Distribution of the indigenous rat flea X. astia on Rattus rattus kandianus
X. Astia index on R. Rattus
Less than 1
1·45 to 1·83
2·02 to 2·51
4·95
Variations in X. astia index are correlated with buildings per acre
LAKE

1928–1929. All Seasons.

Area.	No. of *R. rattus* searched for Fleas.	No. of Fleas.	Flea Index.	No of *X. cheopis.*	Per Cent. *X. cheopis.*	*X. cheopis* Index.	No. of Premises Yielding Rat-fleas.	No. of *X. cheopis* Infested Premises.
Bazaar ...	943	3,023	3·2	808	26·7	0·9	161	102
Commercial ...	157	450	2·9	59	13·1	0·4	37	10
Market ...	355	941	2·6	33	3·5	0·09	76	14
Congested Residential ...	2,328	5,298	2·27	484	9·1	0·21	410	114
Uncongested Residential..	1,900	4,021	2·12	77	1·9	0·04	345	22
"Endemic Plague Zone".	1,701	5,030	2·96	1,216	24·2	0·71	310	188

"Bazaar" Area—Pettah Ward. "Commercial" Area—Fort Ward. "Market" Area—Dean's road and Nagalagam street market areas.

"Congested Residential" Area—St. Paul's, San Sebastian, Slave Island, New Bazaar, and Maradana Wards. The Sea street portion of the endemic plague zone is included.

"Uncongested Residential" Area—Kotahena and Kollupitiya Wards.

"The Endemic Plague Zone" includes the Bazaar area and part of St. Paul's Ward.

Not only are considerable quantities of grain of all kinds dispatched from this district to the Colombo market area and boutiques scattered throughout the town, but consignments are frequently dispatched by motor lorry direct from these plague infected and *X. cheopis* infested premises to up-country stations such as Kandy and to all parts of low-country as well.

4.—Note on the Spread of Plague and Foreign Fleas in the Interior of Ceylon.

Experience in Java and elsewhere shows that outbreaks of plague at the cooler and higher altitudes of hilly tropical islands are likely to be much more severe than those at sea level, where the purely tropical conditions prevail all the year round.

Outbreaks of plague have already occurred in Central Ceylon at Nawalapitiya (1917), Kandy (1920 and 1928), Ragalla (1929), and Galaha (1929). So far they have been successfully dealt with by exceedingly drastic measures of evacuation and demolition of infected quarters in the face of considerable local opposition.

In the view of the writer the risk of grave outbreaks would be small if these hill-country districts retained their primitive rodent and flea fauna, but the recent results of preliminary rat-flea surveys indicate that the dangerous plague carrying species *X. cheopis* is already well established in the belt of tea-planting country lying between the 1,500 and 5,000-foot levels. There is reason to fear that plague may eventually become endemic in this part of the Central Province. All the above-mentioned outbreaks fall within this belt; its climate is particularly favourable not only to the spread and persistence of bubonic plague but also to the reproduction of the carrier insect. Furthermore there is the possibility that the up-country field rodents might become a permanent reservoir of the disease, as in South Africa.

The question now under consideration is what further safeguards, such as grain fumigation, improvements to railway goods sheds, and public and private granaries holding cereals of all sorts, should be adopted to avert the threatened danger to territory of great economic importance with a large indigenous population as well as more than half a million Tamil labourers from the adjacent peninsula. Once plague is definitely established in the planting districts, with their highly developed rail and road communications, proposals for the wholesale fumigation of imported goods will cease to be defensible on epidemiological grounds. In homely phraseology it would be a case of shutting the stable door when the horse had escaped.

The invasion of the higher regions of the Central Province by *Rattus rattus kandianus* and foreign fleas such as the Indo-African *X. cheopis*, the European mouse flea *Leptopsylla segnis*, the fowl flea *Echidnophaga gallinacea*, and the European cat flea *Ct. felis felis* must have followed in the wake of the jungle clearing activities of the coffee and tea planters. It should be borne in mind that until historical times the elevated central area above the Kandyan plateau was, for the most part, virgin forest, with, in all probability, a field rodent fauna of its own infested with the two indigenous up-country fleas, *Ceratophyllus tamilanus*, and the gigantic *Stivalius phoberus*.

On the other hand the establishment of *X. cheopis* in the exceptionally favourable climatic conditions of the Kandyan plateau may well date back to the commencement of the British occupation or even earlier. Reviewing the situation in the light of present knowledge, it seems likely that *X. cheopis* was established on the rats of the harbour premises before it appeared in appreciable numbers in the Pettah-Sea street zone, an event probably contemporaneous with the invasion of that area with plague.

Since the Customs premises are not inhabited at night any rat epizootic which may have occurred in the vicinity of the quays would not be reflected by human mortality from bubonic plague. It is well known that epizootics of rat plague may occur in the harbour premises of large European ports, including Liverpool, Glasgow, and Bristol, without giving rise to more than an occasional case of human plague among the dockyard hands.

We are still very ignorant of the nature of the biological factors which determine the successful invasion of fresh territory by an imported disease-carrying insect, whether it be a tsetse fly carrier of the Trypanosomes of sleeping sickness, an anopheline mosquito carrier of malaria parasites, or a rat-flea carrier of B. Pestis.

It is quite clear that despite the continuous dissemination of *X. cheopis* in grain which must have been going on for nearly twenty years, at least, in low-country Ceylon, this dangerous parasite has not yet succeeded in establishing itself even in the business premises, shops, and godowns of such towns as Galle, Kalutara, Moratuwa, and other towns in vigorous commercial intercourse with Colombo and constantly importing quantities of grain. One *X. cheopis* was found in a collection of 244 rat-fleas from Kegalla, a town near the foot hills of the central mountain zone. On the other hand reference to Table XVII. will show that *X. cheopis* is definitely established at Kurunegala, a town similarly situated to Kegalla in relation to the hills, with numerous boutiques doing a thriving trade in grain imported from Colombo. It would seem that Kurunegala is a potential focus of endemic plague.

Reference to Table XVII. will also show that *cheopis* has appeared in significant numbers at the naval port of Trincomalee.

The results of the recent flea surveys in Kalutara, Galle, Moratuwa, Dehiwala, and the outskirts of Colombo prove that *X. astia* is almost the sole rat-flea of the south-western wet zone of low-country Ceylon, which is relatively immune to plague.

X. astia is a flea of comparatively limited geographical distribution flourishing best under warm and fairly moist climatic conditions. *X. cheopis* is a much more cosmopolitan and much more adaptable species. Hence *X. astia* tends to diminish at the higher elevations of the Central Province and disappear altogether at 6,000 feet, where the climatic conditions resemble those of temperate countries. Confirmatory findings have been made in the Himalayan tracts of the United Provinces, in Madras Presidency, and in Assam.

The facts regarding the solitary specimen of *X. cheopis* so far found in the Kalutara District are most instructive. The boutique in which the rat bearing this flea was found is occupied by a dealer in rice and sundry goods. The rice is imported from Fifth Cross street, Pettah, Colombo, and the sundries from another boutique owned by the same man, also in the Fifth Cross street, Pettah. These premises are heavily infested with *X. cheopis.*

The interior of many countries appears to be naturally protected against serious invasion by plague from overseas. Thus the writer does not believe that Great Britain as a whole is exposed to any considerable danger as long as the outdoor *Rattus norvegicus* and the nesting flea *Ceratophyllus fasciatus* prevail inland. Similarly the epidemiological evidence so far obtained indicates that plague is unlikely to spread to any extent in pure *astia* territory, though sporadic outbreaks may occur if this flea is exceptionally numerous, while experiments show that *astia* is a relatively inefficient carrier as compared with *cheopis.*

It will be seen from Table XVI. that statistically little change has taken place in the distribution of *X. cheopis* in Colombo since the first complete survey was made. On spotting the *X. cheopis* catch on a map, however, it is seen that premises infested with this flea are now much more widely scattered through the districts of Kotahena Central and Wellawatta South than previously. This may be the prelude to its definite establishment in these residential zones.

Attention is drawn to the high *astia* index, 6·21, for commercial premises in Galle. The survey of this port was carried out during the recent small sporadic outbreak of plague, traced to importation from overseas direct to Galle harbour. Probably the epizootic was initiated by a batch of introduced *X. cheopis* and continued for a time by the exceptionally numerous *X. astia.* The ordinary *astia* flea index in the low-country is about 3 ; a figure of this order would seem to signify a high degree of immunity to plague. An *X. cheopis* index of 3, would, on the other hand, be compatible with a severe outbreak of plague during the cooler months of the year.

Preliminary Flea Survey of Ceylon, 1928-1929.

Up-country Results.

	Crude Percentage Proportions of Species.			
	Kandy District. 1928. 1,600 feet. 1,463 fleas.	Galaha-Deltota District. 1929. 3,000 feet. 56 fleas.	Kagalla. 1929. 5,000 feet. 213 fleas.	Nuwara Eliya. 1929. 6,000 feet. 83 fleas.
Xenopsylla cheopis	69·6	58·9	51·6	14·5
Xenopsylla astia	30·4	23·2	0·5	nil
Ceratophyllus tamilanus	nil	nil	5·2	38·5
Leptopsylla segnis	nil	1·8	36·6	32·6
Stivalius phoberus	nil	nil	6·1	12·0
Ctenocephalus felis felis	nil	nil	nil	2·4
Echidnophaga gallinacea	nil	16·1	nil	nil

TABLE XVII.

Results of Low Country Rat-flea Surveys.

		No. of Premises yielding Rat-fleas.	No. *cheopis* infested.	Per Cent. *cheopis* infested.	No. of Rats trapped.	No. of Fleas.	No. of *X. astia.*	No. of *X. cheopis.*	Other species.	Per Cent. *X. astia.*	Per Cent. *X. cheopis.*	Flea Index.	*Astia* Index.	*Cheopis* Index.
Kalutara Health Unit.—6th January to 20th April, 1929.	Commercial premises	80	1	1·2	230	738	736	1	1	99·7	0·1	3.2	3·2	0·004
	Residential premises	145	—	—	426	1,099	1,098	—	1	99·9	—	2·6	2·6	Nil
Galle.—17th August to 20th December, 1929.	Commercial premises	101	—	—	202	1,148	1,146	—	2	99·8	—	5·7	5·7	Nil
	Residential premises	117	—	—	240	816	815	—	1	99·9	—	3·4	3·4	Nil
Kegalla.—2nd to 12th April, 1930.	Commercial premises	17	—	—	38	161	161	—	—	100·0	—	4·2	4·2	Nil
	Residential premises	14	1	7·1	29	83	82	1	—	98·8	1·2	2·9	2·8	0·03
Kurunegala.—13th to 16th April, 1930.	Commercial premises	36	32	88·9	77	325	160	164	—	49·2	50·4	4·2	2·1	2·1
	Residential premises	10	6	60·0	17	57	39	18	1	68·4	31·6	3.4	2·3	1·06
Dehiwala.—14th to 22nd May, 1930.	Commercial premises	15	—	—	36	171	171	—	—	100·0	—	4·7	4·7	Nil
	Residential premises	41	—	—	89	251	250	—	1	99·6	—	2·8	2·8	Nil
Trincomalee.—19th to 20th April, 1930.	Commercial premises	52	15	28·8	200	924	830	94	—	89·8	10·2	4·6	4·1	0·5
	Residential premises	13	2	15·4	54	147	141	6	—	95·9	4·1	2·7	2·6	0·1
Moratuwa.—15th to 23rd July, 1930.	Commercial premises	48	—	—	149	503	503	—	—	100·0	—	3·4	3·4	Nil
	Residential premises	39	—	—	103	332	332	—	—	100·0	—	3·2	3·2	Nil

IV.—Fumigation.

1.—Fumigants in General.

A Commission nominated by the Surgeon-General of the United States Public Health Service postulated the following qualities for the ideal fumigant for plague preventive purposes:—

(*a*) Great toxicity to rats and fleas.
(*b*) Easy recognition by the senses in non-lethal concentrations.
(*c*) Penetrative power.
(*d*) Absence of corrosive action on metals, non-injuriousness to fabrics.
(*e*) Diffusibility when fumigation is over.
(*f*) Non-combustibility and non-explosiveness.

To these may be added, absence of ill-effects on foodstuffs and low absorption by them; rapidity of action; low cost.

The following substances have been tried by various observers :—

(*a*) *Sulphur dioxide* and other gases given off by the combustion of sulphur, *e.g.*, in the Clayton apparatus, or by liberating sulphur dioxide gas from cylinders of liquid SO_2 (one litre of liquid gives about 24 litres of gas). Sulphur dioxide is a heavy gas, specific gravity 2·26, its upward powers of diffusion are comparatively poor. The time of exposure required is comparatively lengthy (6-12 hours for a ship's hold with a similar period for ventilation). The action is uncertain, since any rat on board, alarmed by the odour, may have ample time to escape into covered bilges and other closed compartments into which the gas could only penetrate with difficulty. All fumigants have very poor powers of penetration into such natural rat harbourages through isolated rat holes. Moreover, sulphur gases in the concentrations and time of exposure generally used in fumigation, viz., three per cent. sulphur dioxide and six hours' exposure, attack metals and damage various goods, including coffee, tea, and fabrics.

The great advantage of sulphur fumes is that they fulfil condition (*b*), easy recognition by the senses, better than any other fumigant ordinarily used. Accidents, therefore, seldom follow its use. Sulphur fumigation is a procedure hallowed by time and custom which still has its advantages for some purposes. It appeals particularly to sanitary authorities unprovided with a staff capable of handling substances more dangerous to man, but much more lethal to rats and fleas. Sulphur dioxide has a decided disinfectant action on bacteria.

(*b*) *Carbon monoxide and Carbon dioxide gases* are employed for ship fumigation in some Far Eastern ports. They are generated by the incomplete combustion of coke in the Nocht-Giemsa apparatus. The danger to human life from entry into compartments after fumigation with gas containing a high proportion of carbon monoxide must be of the same order as that associated with the use of the cyanide products, and moreover these gases are ineffective both as pulicides and bactericides. Hence this method cannot be recommended.

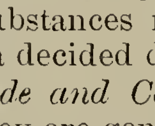
(*c*) *Chloropicrin*, $Cl_3\ CNO_2$, density 1·69, has a relatively slow lethal action on rats in ordinary doses (three hours). In large doses its toxic after-effects may be injurious to the fumigating operators and it is difficult to get rid of the odour after fumigation is complete. It has the same disadvantage as sulphur dioxide, viz., its disagreeable odour has a warning effect on rats. In small doses, however, it is a useful adjunct to other fumigants since its post-fumigation irritative warning effect renders it unpleasant to enter incompletely ventilated compartments after fumigation with such a gas as hydrogen cyanide. The blinking effect on the eye is marked with concentrations in excess of two per million.

(*d*) *Phosgene*, $COCl_2$, carbonyl chloride. This toxic gas, one of those used in projector attacks during the great war, has a comparatively rapid action on rats (one hour) but it is easily decomposed in the warm damp climate of the tropics and rapidly loses its efficacy. It also attacks metals.

(*e*) *Ethylene dichloride* ($CH_2\ Cl_2$) 3 vols. and *Carbon tetrachloride* (CCl_4) 1 vol. mixture. } Specific gravity 1·32.

Mixtures of this type are effective insecticides, they have been used for disinfesting wheat and allied products from weevils and "bran bugs." The cost, however, is excessive and the mixture is too readily absorbed by fatty foods, cacao, chocolate, &c.

(*f*) *Ethylene oxide*,



This fumigant is ruled out by its marked adverse effect on the germination of seeds and grain (Hoyt 1928).

(*g*) Carbon disulphide is an effective fumigant for disinfesting grain from insects, but its vapour is too inflammable and explosive for large scale operations.

(*h*) The cyanide products are considered in detail in the succeeding section.

2.—Cyanide Products.

(*a*) *Liquid Hydrogen cyanide* is available in Europe and America in steel cylinders. The commercial product, as used on the largest scale by the Quarantine authorities at the ports of New York and San Francisco, contains from 96 per cent. to 98 per cent. HCN, the rest being water slightly acidulated with sulphuric acid.

"Considered only as a lethal agent, liquid hydrocyanic acid is the fumigant of choice." (Akin and Sherrard 1928). But it has serious disadvantages which practically rule out its use in the tropics. Liquid hydrogen cyanide may undergo violent decomposition as a result of exothermic reactions in a closed cylinder, associated with polymerisation. "The nature and mechanism of the exothermic polymerisation and decomposition of liquid hydrocyanic acid has been carefully studied by the research chemists of one of the largest American chemical corporations, and the findings of these experts were such as to give rise to the following statement from the manufacturers. This investigation and others made by the same company led to the conclusion that not enough is known about ways and means of stabilizing liquid hydrocyanic acid to warrant its shipment by *common carrier*. Akin and Sherrard (1928).

Recently liquid hydrocyanic acid has been placed on the market absorbed in thin discs of an absorptive material of the nature of wood pulp. The product, known as HCN discoids, can be shipped from New York to Eastern ports in strong tin plate containers. The two containers marketed hold 16 and 40 ounce liquid HCN. The 16-ounce container has 64 "discoids" each charged with ¼ ounce HCN, the 40-ounce container has 80 "discoids" each with ½ ounce HCN. The canisters are opened with a special tin opener, preferably in the open air, while wearing a gas mask and the requisite number of "discoids" scattered in the chamber to be charged. Evolution of HCN is rapid and said to be practically complete within one hour. At tropical temperatures the vapour pressure in the discoid canisters is sufficient to bulge both ends of the tin. It is given by the makers as equal to that developed by liquid HCN, *i.e.*, 3·4 lb. per square inch at 85°F. On first puncturing the tin there is a somewhat alarming rush of gas and air, the makers, however, claim that the actual loss of fumigant is small. After removing the tin lid and substituting a fibre cap the "discoids" can be distributed at leisure by a masked operator. This cyanide product has the advantage of being much more readily transportable than the liquid in cylinders and no apparatus is required for its distribution other than a gas mask and a can-opener. There is no residue except the discs. Chloropicrin can be incorporated in the product if desired. The writer has carried out two trials with HCN "discoids" one in the laboratory store containing bags of rice and fodder in which fleas were buried at surface, four inch, and six inch depths using a heavy dose of HCN and one at the Chalmers Granaries. The kill of rats and fleas was complete in both experiments.

(*b*) *Hydrogen cyanide* may be *generated* from aqueous solutions of sodium cyanide and sulphuric acid. This is the best known method for its preparation. The violent reaction which follows admixture of the two solutions proceeds according to the following chemical equation :—

$$2\,NaCN + H_2SO_4 = Na_2SO_4 + 2\,HCN.$$

The theoretical yield by this equation is not, however, attainable in practice. Hydrogen cyanide is soluble in water and secondary products such as ammonia and formic acid may be formed as well as polymers of HCN itself (Harker, 1921). "The loss due to these causes may amount to as much as 70 per cent. of the total cyanide used." (Stock and Monier-Williams, 1923). According to observations carried at the R.N. experimental station at Stratford (quoted in Stock and Monier-Williams' report, 1923) it would appear that in order to attain the nearest approach to the theoretical yield (94-99 per cent.) saturated sodium cyanide solution should be run slowly into 65 per cent. "chamber" acid using from 10-20 per cent. excess of acid. The yield tends to increase at tropical temperatures. Hence a greater percentage yield or HCN may be expected with such a generator as that of Liston in Colombo than in England.

The gas may be generated inside the compartment to be fumigated by dumping or tipping solid cyanide into receptacles, such as barrels, containing the dilute sulphuric acid. The American regulations for the dumping method give the following proportions between the chemicals employed: 1 ounce sodium cyanide, 1½ ounce commercial sulphuric acid (66°B.), and 2 fluid ounces of water. For the destruction of rodents 5 ounces of sodium cyanide are used per 1,000 cubic feet of air space of to be fumigated with an exposure of two hours; for fleas 2½ ounces and ½ hour exposure is specified ; for mosquitoes ¼ ounce and half an hour ; for lice 10 ounces of sodium cyanide and 2 hours' exposure ; for bed bugs 5 ounces and 1 hour. The theoretical gas concentration for 5 ounces would be 1/437, but probably nothing like this concentration would ordinarily be obtained in practice.

The "dumping" generation methods, with their elaborate and costly arrangements for barrelling holds and getting rid of the dangerous residue after fumigation, have become quite out of date since the introduction of the cyanide powders. They are no longer employed in American ports.

Alternatively the gas may be generated outside the hold in the open air by some such apparatus as the Liston Cyanide Fumigator. Solutions of sodium cyanide and acid are run into the lead-lined generating box and the gas thus generated is diluted with air drawn, by means of a petrol driven fan, through the generating box, thence by means of flexible gas trunks to the compartment to be fumigated and back to the machine. The mixture of air and gas in the compartment is continually circulated. Samples of air can be readily drawn off from the outlet pipe and the concentration of HCN in the circulating gas speedily determined by Liebig's method or one of its modifications. It is a simple matter, therefore, to maintain the concentration at any desired level. The sodium cyanide and sulphuric acid is supplied in half kilo charges which are made up into 50 per cent. solutions for running from separate glass vessels into the generator. The diameter of the inlet and exit trunks is 6 inches and the fan at 3,600 revolutions per minute is capable of delivering 1,200 cubic feet of air per minute along a length of pipe at a pressure of 6 inches on a water gauge. One machine can deal with 60,000 cubic feet of air space at a time.

A machine of this type has been used for the purpose of the experiments in lighters in Colombo harbour and in a fumigating tunnel at this laboratory presently to be described. The advantage of this method of generation is that the dangerous part of the generating operation takes place in the open air so that the risk of accident to personnel is very small. On the other hand this particular machine is of comparatively small capacity so that a number, each with a separate motor requiring maintenance, would be required for the fumigation of a large vessel or capacious warehouse. A port authority would need at least ten such machines.

If it is desired to combine the lethal action of HCN with a tear gas (lachrymatory) warning effect sodium chlorate can be added to a sodium cyanide hydrochloric acid mixture. Cyanogen chloride, CNCl, is then given off. This gas has about half the lethal efficiency of HCN for rats. The tear effect is so pronounced that atmospheres containing more than a trace of this substance are unbearable to human beings. A serious drawback to this warning agent is that the tear effect does not persist any longer, or even so long as the HCN, even in proportions as high as 40 per cent. CNCl. It is protective, therefore, only during the process fumigation itself, whereas, as will presently appear, the real danger is from human entry into compartments insufficiently ventilated after fumigation, hence a post-fumigation warning lachrymatory effect, such as that given by chloropicrin is much more useful in practice. HCN may also be combined with 20 per cent. cyangoen chloride in liquid form in cylinders. According to Akin and Sherrard there is not much to choose between the lethal action of pure HCN and this mixture ; if anything pure HCN has the advantage.

(*c*) *Calcium cyanide* gives off HCN gas on simple exposure to moist air. The American product is sold in various forms in tins or buckets with friction tops. Liberation is very rapid in the moist warm atmosphere of Colombo and, probably, less than 5 per cent. of the original HCN content remains unliberated at the end of two hours.

The formula may be given as $Ca(CN_2.)$ The substance used daily in this laboratory for the fumigation of live rats brought to the laboratory for flea survey purposes is the Cyanogas A powder. It takes the form of a light dust and has a light tan colour. It is purchased for this purpose in 5 lb. tins. Granular forms liberating cyanide more slowly are also available. These materials are bye-products of the cyanamide manure industry and are prepared by the action of slightly moist hydrocyanic acid on calcium carbide, acetylene being liberated. According to Schwarz and Dochert (1927) cyanogas dust gives the following analysis :—

41 per cent. calcium cyanide,
32 per cent. calcium cyanamide.
0·4 per cent. calcium carbide.

According to the manufacturers about half the weight is available as HCN.

For fumigation purposes the dust may either be blown into the compartment to be fumigated or spread out in thin layers on the floor. The former method gives the highest yield of HCN, but the dust clings everywhere and as the action is reversible and HCN may be taken up by the residue it is dangerous to handle ; whereas if the material is spread out on sheets of paper, &c., it can be easily and safely removed after fumigation is complete.

(*d*) *Zyklon B.* is the trade name of a German product. It consists of an infusorial earthy substance called diatomite absorbing about an equal weight of liquid HCN plus various amounts of chloropicrin (10 per cent., 6 per cent., or 4 per cent). This addition enables the useful post-fumigation warning lachrymatory effect to be obtained. The cyanide impregnated earth is sold in heavy tins capable of sustaining a pressure of five atmospheres which can be transported with perfect safety by ordinary carrier. The cans are issued in varying sizes containing a guaranteed HCN content of 20, 100, 500, 1,000, or 1,200 grammes. On opening the cans, *e.g.*, with a special cutter in one stroke, the material can readily be poured out of the can into the compartment to be fumigated. Owing to the great surface area of diatomite, evolution of the absorbed cyanide is very rapid and so complete that at the end of the customary two hour fumigation period the residue is practically inert. There is no tendency for this residue to re-absorb gaseous HCN. It may, therefore, be safely left *in situ* though it is advisable to sweep it up in order to obviate persistence of the chloropicrin odour and its tear effect.

There can be no doubt that the introduction of these adsorbent of liquid HCN represent a marked advance in cyanide fumigation technique. Probably there is nothing much to choose between Zyklon B. and HCN discoids. In practice their use is simplicity itself, and, according to Akin and Sherrard the cost per pound of HCN yielded by Zyklon B. in New York is equivalent to that of liquid hydrogen cyanide as manufactured in the United States.

3.—Physical Properties of Hydrogen Cyanide Gas.

Pure hydrogen cyanide is a colourless combustible liquid boiling at 26·5°C. at atmosphere pressure. It is soluble in all proportions in water, alcohol, and ether. Liquid HCN is liable to polymerise when a trace of alkali is present, but when pure or slightly acid it can be preserved unchanged. The density of the gas relative to air as unity is 0·95. It, therefore, tends to rise when liberated.

The distribution of hydrogen cyanide generated by the dumping method or by the Liston Cyanide Fumigator in ship-holds and superstructures has been studied by Glen Liston and Stock and Monier-Williams. Experimental observations were carried out by Akin and Sherrard at New York working with two gastight adjoining rooms communicating through three short sections of 2-inch iron pipe perforating the partition wall at equal intervals along the mid-perpendicular line from floor to ceiling. Test animals exposed near the ceiling of the room into which the gas was introduced were invariably killed before animals placed on the floor equidistant from the point of introduction of the fumigant. HCN gas diffused very slowly into the next compartment in the absence of artificial convection currents, such may be set up by unsealing the windows and allowing air to flow in through small openings round the frames.

"The conclusions regarding hydrocyanic gas diffusion in the usual fumigating procedures may be briefly summed up by stating that no ordinary concentration and no ordinary exposure time will insure the infiltration of gas into so-called dead spaces commonly communicating with compartments under gas through such small openings as are customarily used by rats. The opening up or complete elimination of such small contiguous spaces and the competent blocking of such escape openings will therefore be considered as of equal, if not greater, importance than the gas dosage, the exposure time, or the kind of fumigant used. *A vessel not thus carefully prepard for fumigation will more or less nullify the potential good effects of the most careful gassing.* (Akin and Sherrard.) It seems scarcely necessary to stress the great practical importance of this conclusion for all kinds of fumigating work.

Lutrario (1928) has also studied the action of HCN gas in specially constructed cabins of 20-cubic meters and 80-cubic metres capacity at an experimental station near Rome. Samples of air were aspirated from different points of the chamber after liberation of the gas and the HCN content determined in the usual manner. As a result of repeated trials it was established that 30 minutes after the commencement of the generative reaction (sodium cyanide and sulphuric acid) the gas was distributed nearly uniformly throughout the chamber.

The specific gravity of a mixture of air and hydrogen cyanide gas in normal fumigation proportions (2 ounces of HCN per 1,000 cubic feet of air) if very close to that of air alone. It should be realized that no gas mixed with a large volume of air can be separated by gravity. Hence it is futile to expect that HCN will rise out of a ship-hold, lighter, or other compartment through hatches and ventilators. The clearing of a compartment after fumigation depends on convection, *i.e.*, the

movement of air currents, and not on diffusion. Usually there will be sufficient breeze blowing to rapidly clear a large empty compartment of poisonous fumes, but it is not safe to depend upon the climatic conditions. Artificial ventilation should always be employed, where practicable, to get rid of gas retained in holes or pockets.

An aerothrust apparatus is employed by the United States Public Health service for clearing ships of cyanide fumes. According to Stock and Monier-Williams, it consists of a two cylinder, two cycle, air-cooled 3 h.p. gasoline engine, driving a two-bladed propellor 32 inches in diameter at a speed of 1,600 revolutions a minute. It is said to deliver over 22,000 cubic feet per minute. "The blast from the machine if directed down a companion way will do more in a few minutes, frequently, than natural ventilation will do in several hours. Even more time may be saved by the machine when sulphur dioxide is the fumigant." (Grubbs).

One of the advantages of the Liston Cyanide Fumigator is that it combines the functions of generation and delivery of the cyanided air with ventilation by forced draught after fumigation. All that is necessary is to disconnect the return pipe to the generator and run the motor.

4.—The Lethal Action of Hydrogen Cyanide Gas.

Since both time and concentration are factors in the lethal action of hydrocyanic acid gas, its toxicity is most suitably expressed by concentration time curves for each animal under consideration, for plague work rats, fleas, and human beings. Inhaled HCN gas is continously destroyed in the body, death only resulting when the rate of absorbtion exceeds that of destruction.

Barcroft (1931) obtained the following results in the course of a series of experiments carried out at the War Department Experimental Station in an airtight plate glass chamber fitted with a fan for stirring the poisoned air :—

Animal,	Lethal exposure time for a concentration of 1·0 mg. to litre minutes.	Animal,	Highest approximate concentration which can be breathed indefinitely mg. per litre.
Dog ...	0·8	Dog ...	0.10
Mouse ...	1·0	Rat ...	0·10
Cat ...	1.0	Mouse ...	0·14
Rabbit ...	1·0	Rabbit ...	0·18
Rat ...	2·0	Monkey ...	0·18
Guinea-pig ...	2·0	Cat ...	0·18
Goat ...	3·0	Goat ...	0·24
Monkey ...	3·5	Guinea-pig ...	0·40

Man is relatively resistant. In experiments during the war men have been exposed to concentrations as high as 500 parts per million for about a minute without injury. Canaries are extremely sensitive to HCN, 1-10,000 parts been fatal in about two minutes. These birds, therefore, are specially useful as indicators of the presence of HCN fumes, more so than the white rats and mice commonly employed for the purpose. Pigeons vomit at about the same concentration.

Experiments on goats indicate that the time of exposure required to produce unconsciousness and collapse is only about one-third the fatal period.

Hydrogen cyanide gas inhibits the action of the intracellular enzymes of the body particularly those responsible for the oxidative life of the tissues. The actual cause of death when small doses are taken is paralysis of the respiratory centre. The initial symptoms are giddiness, headache and faintess, confusion, palpitation and pain in the chest and region of the heart; difficulty in breathing, ending in unconsciousness, then supervenes.

In the United States the standard fumigating dose is 2 ounces of HCN per 1,000 cubic feet. Akin and Sherrard determined the effect of fractions of the standard dose on rats using liquid HCN-CNCl mixture, liquid HCN calcium cyanide, HCN generated alone, and the HCN-CNCl mixture generated.

Allowing for the variation in resistance in test animals, the average killing time for fractional doses when using liquid hydrocyanide acid, mixed and alone, may be accepted as follows :—

Dose.		Time.
One-quarter ounce HCN per 1,000 cubic feet	...	15 to 20 minutes.
One-fifth ounce HCN per 1,000 cubic feet	...	20 to 25 minutes.
One-sixth ounce HCN per 1,000 cubic feet	...	30 to 45 minutes.
One-eighth ounce HCN per 1,000 cubic feet	...	60 to 180 minutes.
One-tenth ounce HCN per 1,000 cubic feet	...	Overnight.

Animals withstood still smaller doses for as long as 36 hours without ill-effect.

Glen Liston worked on the basis that 20 parts per 100,000 of HCN in air are lethal to rats in half an hour. Dogs and cats are very susceptible to cyanide.

Creel and Faget (1916) carried out a number of experiments on the lethal concentration of HCN gas for the destruction of insects. They advocate the following proportions of potassium cyanide for use by the generation method. It should be remembered, however, that the actual yield of HCN would be much below the indicated theoretical. The figures are of value as showing the relative resistance of the respective insects to the fumes :—

Kind of Insect.		Weight of HCN per 1,000 Cubic Feet.		Exposure Time.
Mosquitoes	...	0·4 ounces	...	Fifteen minutes.
Bed bugs	...	5 ounces	...	One hour.
Body lice	...	10 ounces	...	Two hours.
Cockroaches	...	10 ounces	...	One hour.
Fleas ...	...	2½ ounces	...	Fifteen minutes.

The common flour and grain weevils are relatively resistant, much more so than fleas. In the course of the experiments on the fumigation of grain recorded later, it was frequently observed that weevils survived long after all fleas were dead.

The observations of the writer indicate that fleas are extraordinarily sensitive to hydrogen-cyanide gas. Concentrations of the order barely sufficient to turn a benzidine acetate test paper blue have a stupefying effect on fleas freely exposed to the action of HCN gas at tropical temperature and slightly higher concentrations are rapidly lethal.

It should be clearly understood that hydrogen cyanide is useless as a bacterial disinfectant. It does not kill the plague bacillus but is the most efficient agent known for the destruction both of plague rats and the rat-flea carrier of the infection.

Experiment (1).

The results of an experiment on the relative viability of the imagines, larvæ, and pupæ, of *X. astia* exposed to HCN gas are set forth below :—

An open petri dish covered with a layer of cotton wool was placed at the bottom of a four litre glass jar ; 15 ♀ and 34 ♂ *Xenopsylla astia* taken alive off rats that morning were placed upon the wool. All manifested marked activity. Another open dish was super-imposed immediately above this containing 12 *X. astia* larvæ and 2 pupæ. Slips of benzidine copper acetate paper and mercuric methyl orange paper (strong solution prepared as recommended by Sherrard, 1928), were also placed on the top dish. Hydrogen cyanide gas generated from sodium cyanide and sulphuric acid in a 10 cubic feet galvanized iron bin was introduced through a glass tube at the bottom of the jar, and drawn out through another at the top connected through a caustic soda wash bottle to a five litre aspirator. After allowing time for the attainment of gaseous equilibrium in the bin after completion of the reaction, the cyanide impregnated air from the bin was drawn through the jar at an approximately uniform rate of 4 litres per 13 minutes. The course of events in the jar was approximately as follows :—

One minute.—Benzidine copper acetate paper turned blue, change began at 40 seconds. Mercuric methyl orange paper commenced to turn red in 60 seconds.
Two minutes.—Larvæ stimulated to greater activity. 30 seconds later activity of fleas commenced to increase. For about one minute the increase in activity was very marked, after which fleas began to collapse.
Five minutes.—Most of the larvæ and fleas entirely inert.
Eight minutes.—All larvæ quiescent.
Nine minutes.—All fleas quiescent.
Thirteen minutes.—Lid removed and petri dishes withdrawn and freely exposed to air.

Half an hour later 3 fleas began to revive, the following day 5 live fleas were found, the remaining 42 were quite dead. There were no larval revivals.

The two pupæ did not hatch out. The 4,100 c.c. of air aspirated through dilute caustic soda showed 20 parts of hydrogen cyanide per 100,000 by Liebig's silver nitrate method. (Potassium iodide crystals were added to the dilute caustic soda solution in all the determinations recorded.) This represents the mean concentration. The rise to maximum concentration would be slow at first. According to Sieverts and Hemsdorf benzidine acetate cyanide test paper shows a pale blue tint after 10 seconds exposure to 2·8 grammes HCN per 1,000 cubic feet. In this experiment the larvæ (first instar) showed themselves slightly more susceptible to cyanide than the fleas. The HCN concentration used is lethal to rats after half an hour's exposure.

5.—The Effect of Hydrogen Cyanide Gas on Foods and Fabrics.

The action of HCN on different substances has been studied by Lutrario (1928), Buttenberg and Weiss (1924), Monier-Williams (1930), and others. The absorption of cyanide by wheat and its derivatives treated by calcium cyanide has been investigated by Swanson and Working (1926).

In general the results obtained may be briefly summarized as follows :—

(*a*) Liquids, including milk, water, and watery products, take up hydrogen cyanide freely and uniformly in solution. Hence the importance of protecting or draining fresh drinking water tanks, milk vessels, meats, &c., in ships or lighters when fumigation is in progress.

(*b*) Saccharine substances, such as honey, marmalade, or syrup may absorb and retain appreciable quantities of HCN in the superficial layers exposed to its action.

(*c*) Fatty substances may retain traces of HCN after fumigation.

(*d*) High concentrations of the gas affect the flavour of tea, coffee, and tobacco ; vegetables, such as celery, cabbages, and lettuce wilt and lose their marketable value ; peaches and dessert pears may be shrivelled and discoloured.

(*e*) Woollen stuffs may retain sensible quantities of HCN which is given off slowly at room temperature but rapidly when warmed to temperatures between 35° to 50°C.

(*f*) Cotton wool may absorb a notable quantity of gas which, however, is rapidly given off again on simple exposure to air.

(*g*) Cyanide may penetrate thin skinned fruits if the concentration is high and the exposure prolonged and combine with saccharine substances in the superficial layers of the fruit. HCN forms a stable cyanhydrin in foods containing lævulose.

(*h*) Hydrogen cyanide is absorbed by the surface of grains, including rice grains. If such fumigated grains are exposed to air in thin layers the HCN is rapidly and almost completely given off again but the gas may take some days to diffuse out of a heavily dosed bag of grain.

(*i*) Grain and cereals of all kinds exposed repeatedly to heavy doses of hydrogen cyanide do not lose their power of germination.

(*j*) Animals fed with ventilated cyanide fumigated foodstuffs show no signs of intoxication.

In no case did Buttenberg and Weiss find more than 3 milligrammes of HCN in fumigated fruits, vegetables, coffee, tea, cacao, chocolate, cereals, flour, fats, and tobacco, and usually the amount was below 1 milligramme per 100 grammes. According to Lehman the dose tolerated by human adults is 10 to 12 milligrammes ; 60 milligrammes would be a fatal dose.

Generally speaking, in the case of ordinary dry foodstuffs, any cyanide superficially absorbed is rapidly given off on free exposure to air. The last traces would be removed or oxidized in subsequent operations and on cooking.

6.—Precautions to be taken in Cyanide Fumigation.

The cyanide product itself requires to be handled with care. The safest from this point of view seem to be Zyklon B. or HCN discoids since the tins are of strong construction and will withstand very rough treatment, *e.g.*, banging against a wall or dropping from a height, without risk of leakage of contents. The operator engaged in opening tins of cyanide powders should wear a respirator, a large volume of gas may suddenly escape from tins with bulging ends. Sodium cyanide solutions, as used in the Liston Cyanide Fumigator, should only be made up by trained personnel. The acid and cyanide solutions should not be left unattended side by side.

In port practice some sort of warning signal should be hoisted where cyanide fumigation is in progress, *e.g.*, a red flag. The fumigation operations should always be in charge of some responsible officer on the spot. The real danger associated with fumigation with cyanide arises from premature attempts to enter insufficiently ventilated spaces after fumigation is over. The poisonous gas is apt to collect in pockets or compartments relatively inaccessible to the blast of the ventilating fans or to natural currents of air. It may be absorbed to a dangerous extent by débris in bilges which should be pumped clear.

Before anyone is permitted to enter a space, such as the hold of a lighter or ship, a live rat or mouse enclosed in a cage should be lowered by means of a rope into the space to be entered. These animals are much more susceptible to cyanide fumes than man himself and if they exhibit no signs of embarrassment within ten minutes it is perfectly safe to descend into the tested compartment. The use of the cyanide test papers prepared after the manner recommended by Sherrard (1928) enables the presence of a dangerous concentration of gas to be detected. This method, however, is not so simple or sure as the animal test, not only must the papers be well prepared but the time taken in turning colour requires to be accurately noted with a stop watch.

No one should be permitted to travel about the interior of a ship after fumigation until some competent person equipped with a properly fitted oxygen breathing apparatus has tested all doubtful compartments and passed the ship clear.

In the United States Quarantine Service a medical officer is in responsible charge of fumigating operations on board ship. At Liverpool the following certificate is issued by one of the medical officers of the Port Sanitary Authority after completion of fumigation of ships with cyanide gas :—

> "I certify that I have tested the ss. . . . . in all parts, and found the vessel to be free from hydro-cyanic acid gag in quantities dangerous to human life. The vessel is now safe for any person to go on board."

In the case of lighters special attention should be directed to the ventilation of fore and aft peaks which are commonly inhabited by coolies in charge of the lighter. The bulkheads between these compartments and the main hold of the lighters are seldom gastight.

The personnel actually handling the fumigants on board ships or lighters should be provided with box respirators. The usual type, such as that supplied with the Liston Cyanide Fumigator, has a face-piece covering the nose, eyes, and mouth and the box contains the standard mixture of activated charcoal and alkaline permanganate granules. It is simpler to use than the oxygen breathing apparatus.

Cyanide products are safely used on an enormous scale for the fumigation of citrus trees from pests and other agricultural purposes in California, Egypt, and elsewhere. The operations are conducted in the open air. The writer has been unable to trace any record of accident following open air cyanide fumigation. Cyanide gas has been found to be useless in war as an offensive weapon on account of the great rapidity with which the fumes are dispersed when ventilation is free.

Detailed instructions for rendering first aid to persons overcome by cyanide fumes are given in the recent brochure issued by the Ministry of Health, Whitehall. The specified materials should be at hand when fumigation operations are in progress.

7.—Penetrative Powers of Hydrogen Cyanide Gas, with Notes on the Behaviour of Rat-fleas in Grain.

(*a*) *Anti-rodent Action.*

Reference may be made to the investigations of Akin and Sherrard (1928) into the penetration of hydrogen cyanide gas into permeable materials serving to protect rats from the lethal action of a fumigant.

As already indicated, these observers conclude—on the basis of numerous experiments—that rats escape fumigation either because they were already safely harboured in a dead space relatively inaccessible to the gas, or because they have time to seek refuge in such enclosed spaces at the onset of fumigation before a lethal concentration of HCN has been attained. As Akin and Sherrard point out, it is to such closed spaces that rats "instinctively turn when menaced by the introduction of gas or disturbed by the preparations incident to the proposed fumigation." On the other hand they attach much less importance to the protection afforded by ordinary cargo in ships' hold or compartments. "Hydrocyanic acid gas will penetrate either bagged or loosely boxed parcels if the gas is permitted to *surround* the container." The writer's own observations and experiments lead him to the same conclusion.

Akin and Sherrard carried out a number of experiments to test the power of HCN gas to penetrate into spaces containing live rats partially protected by various means. Thus white rats were placed in gastight boxes having from one to four quarter-inch holes bored in one end. All rats exposed to a 2-hour fumigation with the customary 2 ounces per 1,000 cubic feet concentration of HCN were killed when ensconced in boxes with two or more holes. All the rats in boxes with no holes escaped. Similarly, test animals were placed in open mesh wire cages in gastight buckets securely closed at the top by pads of new gunny sacking in layers 10 to 80 thick, dry in one series of experiments, wet in another. With dry bags test animals were invariably *killed* through 70 layers. Eighty layers always protected. When *wet* sacking was used, test animals were invariably *protected* by 40 layers. The wet sacks were prepared by saturating them with water, wringing them out as dry as possible, and then hanging them out in the air for one hour.

Rats protected by four layers of sacks made of kraft paper were *killed.* "Rats protected by from 16 to 20 layers of blankets, and others rolled in matting or hidden in piles of loose sacking were invariably killed by the standard dose and exposure."

Four sources of HCN were used in these instructive experiments, liquid HCN-CNCl mixture, Zyklon B. generation method, and calcium cyanide. The best results were obtained with the two former substances, doubtless as a result of greater rapidity of evolution of HCN and more prompt attainment of a lethal concentration. With calcium cyanide the requisite concentration can be readily reached by correct adjustment of dosage, but the rise in HCN concentration is slower. The generation method turned out to be the slowest and, as already pointed out, there is greater uncertainty as to the concentration reached from the given weight of materials used. At tropical temperatures velocity of reaction and diffusibility of HCN through permeable materials are likely to be enhanced as compared with average conditions at New York.

(*b*) *Pulicidal Action.*

According to Lutrario effective penetration of grain enclosed in ordinary sacks by hydrogen cyanide gas is limited to the peripheral layers as regards lethal action on insects. Thus he states that the parasiticide action against *Hœmatopinus suis* does not extend deeper than 5 to 6 centimetres. The observations carried ont in this laboratory on the viability of mites in grain bags are in conformity with this result. He also states, however, that chemical determinations have revealed the presence of HCN even in the deepest layers of such bags.

Anderson (1923) found that $3\frac{1}{2}$ to 4 hours' exposure to hydrogen cyanide gas was sufficient to kill all weevils and other insects infesting the grain. Grain fumigated six to eight times still germinated rapidly. When kept for some three months such grain showed no signs of reinfestation thus indicating that the reproductive forms of the insect had also been destroyed.

For the purpose of this report, the primary consideration is the penetrative power of HCN into bagged materials, especially rice and other forms of grain infested with rat-fleas. This point has been insufficiently investigated hitherto. The extreme susceptibility of such fleas as *Xenopsylla cheopis* and *X. astia* to cyanide fumes does not appear to have been generally realized. Rice weevils are far more resistant to hydrogen cyanide than rat-fleas.

Flu and de Vogel carried out experiments on the disinfestation of rice with steam at 60°C. and sulphur fumes from rice weevils and fleas. It was found that rice weevils withdrew from the action of both the steam and the sulphur fumes into the depth of the rice. Observations on miniature gunny bags put into bottles with the rat-flea *X. cheopis* also demonstrated a similar tendency for the fleas to burrow between the strands of the gunny bag and bury themselves in the rice when exposed to action of SO_2 gas.

It seems to be the commonly accepted view that complete disinfestation of bagged grains and similar permeable products from fleas is scarcely practicable without the assistance of a vacuum to enable the hydrogen cyanide to penetrate through the material exposed to its action. It will be demonstrated in this report that this view is incorrect. Given an adequate concentration of HCN in the air surrounding the individual bags and a long enough exposure, the complete disinfestation of bags containing large or medium grains, including the chief varieties of rice in the Eastern market—save those largely composed of rice grains broken into fragments—is quite feasible and practicable without injury to the grain, though somewhat prolonged and free ventilation subsequent to fumigation may be required to eliminate all but the last traces of HCN from the disinfested product, if high concentrations of this fumigant have been employed.

It may be argued that it is unnecessary to aim at such complete penetration since only a small proportion of fleas will normally be found in the depths of such permeable materials as rice.

The observations of Flu and de Vogel and those by the writer recorded in the succeeding section demonstrate that the more active fleas can and do tend to escape from the action of a fumigant applied to the surface of a grain bag by withdrawing away from the gas towards the centre of the bag, though, in all probability, they would seldom succeed in doing so if confronted with a concentration of HCN rapidly rising high above the minimum lethal dose for fleas.

(*c*) *Behaviour of Rat-fleas in Grain.*

It is important, therefore, to consider the behaviour of rat-fleas released in the vicinity of a bag of grain by death of their natural host, the rat. The observations of Flu (1921) on the epidemiology of plague in the Dutch East Indies, to which brief reference has already been made, throw a flood of light upon this question. The first observations were carried out, like the above-mentioned experiments on rice disinfestation, at Kerta Patih, a river port at the terminus of the South Sumatra Railway and at Palembang, an important grain import centre, lower down the river Moesi. Rice from the rice bags in the magazines was spread out in a layer and rabbits loosed upon it. On one of the rabbits plague infected *X. cheopis* was found. The investigation was continued at Tandjong Priok, the port of Batavia, in the large warehouses along the quay, using guinea-pigs as flea traps. Even in uninfected warehouses many *X. cheopis* were recovered from the guinea-pigs, although many warehouses did not contain materials specially attractive to rats.

When rat plague appeared in these same warehouses the experiments were repeated. An increased number of *X. cheopis* were recovered from the guinea-pigs. These fleas were more numerous in the stores holding goods attractive to rats such as rice, dried fish, and flour. Many fleas were found to be plague infected.

The possibilities of transferring such infected rat-fleas in grain bags were then investigated. Fleas were placed in bags in the warehouse itself and their behaviour observed. Many crawled over the surface of the bag, a few crawled between the strands of the gunny bags or even penetrated into the rice itself. Such fleas were subsequently recovered by opening the bag, spreading out the rice, and allowing guinea-pigs access to it. "When the bags in which the fleas are housing are transported, the fleas go with them. If there happen to be fleas infected with plague among these transported ones, then there is a chance of the plague being imported with the bags of rice."

The results of the Colombo experiments specially designed to test the penetrability of grain to HCN gas are set forth below. Attention is particularly directed to the results obtained with different kinds of grains in the fumigating tunnel series of experiments and the later experiments on the fumigation of rice in lighters which are confirmatory of the conclusions reached from the experiments in the grain jar *qua* the lethal action of HCN gas on rat-fleas buried at various depths in grain.

The ova, larvæ, and imagines of rat-fleas buried in the centre of sacks of muthusamba, malkora, and milchard rice can be completely killed by exposing the isolated sacks to a forced draught of air at tropical temperature impregnated with about 2 ounces of hydrogen cyanide per 1,000 cubic feet, *i.e.*, the standard U. S. concentration, for 40 minutes.

The results of the fumigating tunnel series with artificially wetted bags indicate that a similar result can be obtained at the cost of a moderate increase in concentration of HCN. With the fine grains, however, effective central penetration is not obtained even in one hour with concentrations of the order of 150-200 parts per 100,000.

For practical plague preventive purposes, however, it will probably suffice to aim at sufficient penetration of HCN gas to turn a benzidine copper acetate test paper blue at a depth of six inches. Judging from the data obtained in the tunnel series of experiments such a result may be obtained with the standard U.S. concentration and a half-hour exposure of isolated bags to a continuous blast of cyanided air.

8.—Laboratory Tests of the Penetrability of Rice by Hydrogen Cyanide Gas.

In these experiments an inverted Bulloch anaerobic jar was used in the manner illustrated in the Plate

Experiment (2).

The jar was filled to a depth of five inches with malkora rice. Test papers were prepared from benzidine acetate copper acetate solutions (Sherrard, 1928). One was placed at bottom centre of jar so as to be visible underneath, one at two inches depth towards side so that the edge was visible through glass side of jar, and one at centre of surface.

HCN gas (concentration 145 parts per 10,000) was passed continuously over the surface of the rice. Two minutes after opening the aspirator cock the surface paper had turned deep blue. At the fifth minute the two-inch paper had commenced to turn blue. The edge of the bottom paper turned blue faintly after 15 minutes.

Experiment (3).

Several experiments were carried out in the fumigating jar to test the behaviour of fleas exposed to a rising concentration of HCN. In the first malkora rice placed in the 4,200 cc. jar to a depth of six inches was covered with a circular layer of jute gunny bag. Twenty-four fleas taken alive were placed on the surface of the jute. The fleas showed no tendency to penetrate into the rice when the jar contained pure air. Hydrogen cyanide gas (concentration 200 p.p.h.) was then turned on very slowly. The fleas were stimulated to great activity. Within five minutes several were observed to penetrate the interstices of the layer of jute gunny bag and soon some could be seen at the side of the jar at a depth of three inches beneath the surface of the rice. The HCN gas-air mixture was then run through for ten minutes. Mean HCN concentration in jar 75 parts per 100,000. At the conclusion of the experiment fleas were found to be distributed through the rice as follows :—

12 on the jute sacking,
3 just beneath jute sacking,
5 at depth of 1-2 inches,
2 at depth of 2-4 inches,
1 at depth of 4-6 inches,
1 actually at bottom centre of jar having completely penetrated the rice in its endeavour to escape from the slowly rising concentration of HCN.
All fleas killed.

Experiment (4).

In a second such experiment with malkora rice using an HCN concentration of 180 p.p.h. the aspirator tap was opened full from the start and run for 12 minutes.

As before, the fleas were at first stimulated to increased activity, but all surface fleas appeared to be asphyxiated at the end of three minutes. The results of the depth flea counts were as follows :—

0-2 inch ... ... 14 fleas
2-4 inch ... ... 4 fleas
4-6 inch ... ... 1 flea
All fleas killed.

Experiment (5).

One of the most instructive experiments of this series was carried out with a six-inch layer of fine parboiled rice. Duplicate mercuric-methyl orange full strength test papers were placed in position at top, middle, and bottom of the jar; 36 *X. astia* were placed on the surface of the rice. The concentration of HCN employed was low, mean 34 p.p.h., and the duration of the

experiment 45 minutes, viz., until the bottom centre test paper had turned distinctly red. Rate of aspiration one litre every three minutes. The course of events was as follows :—

Surface test papers began to change colour ...	45 seconds
Fleas showed increased activity at	50 seconds
All fleas inactive	3 minutes
Middle test papers ($2\frac{1}{2}$ inch deep) began to turn red ...	7 minutes
Bottom test papers began to turn red at edges ...	37 minutes
Bottom test papers distinctly red, lid of jar lifted ...	45 minutes

	Distribution of Fleas in Rice at end of Experiment.		Distribution of Fleas in Rice at end of Experiment.
0-1 inch	14	3-4 inch	3
1-2 inch	12	4-5 inch	Nil
2-3 inch	6	5-6 inch	1

Three fleas eventually revived. Thirty-three killed.

9.—Preliminary Observations on the Penetration of a Single Rice Bag by Hydrogen Cyanide Gas.

A number of experiments were undertaken with a view to obtaining a rough idea of the rate of diffusion of cyanide gas into the interior of a flea infested rice bag, when the concentration of the gas in the air surrounding the bag was of the order commonly used in fumigation.

$4 \times \frac{1}{2}$ inch glass tubes containing live fleas and their eggs lightly plugged with cotton wool were buried :—

(*a*) At centre of the central axis of the bags henceforward designated central C. fleas in Tables XVIII. and XIX.

(*b*) Half-way between central axis and gunny bag opposite the former tubes. M. fleas in Tables.

(*c*) Just beneath gunny bag. S. fleas in Tables.

The rice used in these experiments was an inferior quality small grain. The bag was placed in a galvanized iron bin of ten cubic feet capacity provided with a tight-fitting lid which was perforated with two holes to take corks. When the HCN was generated from sodium cyanide, sulphuric acid was run into the bin from a separating funnel fitted to one cork into a shallow beaker below containing the appropriate amount of potassium cyanide solution. A tube passed through another cork led to a caustic soda wash bottle and thence to a five-litre aspirator. By titrating the caustic soda with standard silver nitrate solution the concentration of HCN in five litres of the air surrounding the bag drawn off could readily be determined. The results are set forth in Table XVIII. Some of the fleas under the survival column were stupefied when first observed, but subsequently revived. From 6 to 12 fleas were used per tube and in most instances duplicate tubes were placed in the positions indicated.

The results, as a whole, including those obtained in the fumigating tunnel described later, serve to exhibit the importance of the time factor in assuring complete penetrability of permeable materials by cyanide fumes in effective pulicidal concentration.

TABLE XVIII.

Experiments (6) *to* (9).

Cyanide Fumigation of Single Rice Bag in closed Bin.

	Quantity of Fumigant used.	Mean concentration of HCN in Air of Bin. Parts per 100,000.	Time of Exposure. Minutes.	Effect on Fleas.						Remarks.
				Killed.			Survived.			
				S.	M.	C.	S.	M.	C.	
VI.	20 grams potassium cyanide solution and acid.	180	15	12	18	nil	nil	nil	30	M tubes only 3 inches deep.
VII.	30 grams calcium cyanide.	230	30	36	36	nil	nil	nil	24	
VIII.	20 grams calcium cyanide.	210	45	—	18	42	—	nil	nil	Tubes along central axis of bag. All eggs failed to hatch.
IX.	30 grams calcium cyanide.	190	60	12	12	48	nil	nil	nil	No larvæ developed from numerous eggs. Tubes inserted above and below central point.

10.—Investigation into the Penetration of Hydrogen Cyanide Gas into various Grains exposed to a forced Draught of Cyanided Air.

For the purpose of this series of experiments a tunnel 40 feet long, 3 feet wide, and 3 feet high was erected on the verandah of the laboratory (see the Plate I.) by the Staff of the Harbour Engineer. The tunnel was constructed of a wooden framework covered with stout canvas well tarred all over to reduce its permeability to HCN. One side of the tunnel was fitted as a flap with wooden edging to fasten securely with bolts and thumbscrews against the felt-lined framework of that side when fumigation was in progress. When free it could be lifted away from the side to enable the grain bags to be introduced. The bottom wooden edge of this flap was perforated with a series of holes fitted with corks through which glass tubes could be passed into the midst of each grain bag, thus permitting samples of air to be aspirated off for estimation of the interior HCN concentration while fumigation was in progress. The ends of the tunnel were closed with canvas covered wood fitted in the centre with a six inch diameter tin socket suitably slotted for connection with the main gas trunks of the Liston Cyanide Fumigator.

THE GRAIN FUMIGATING TUNNEL. THE ASPIRATORS ARE CONNECTED TO TUBES LEADING TO THE CENTRE OF THE GRAIN BAGS.

LABORATORY APPARATUS FOR TESTS ON THE MOVEMENT OF FLEAS IN RICE AND THE PENETRABILITY OF RICE BY HCN GAS.

250 c.c. graduated separating funnels were substituted for the sodium cyanide and sulphuric acid glass solution containers supplied with the machine to enable the dose of HCN applied to a cubic space of only about 400 cubic feet, inclusive of fumigating apparatus, to be regulated with reasonable accuracy. The machine is designed to deal with 60,000 cubic feet. The machine was ordinarily run at about 1,800 revolutions per minute. The volume of air circulated through the gas trunks may be roughly put at 600 cubic feet per minute. The cyanided air was therefore in vigorous circulation. Each bag rested on brick supports laid upon the canvas bottom and was thus freely exposed on all sides to a continuous blast of cyanide gas.

Preliminary tests enabled the rate of addition of the 50 per cent. solutions of sodium cyanide and sulphuric acid to be suitably regulated to maintain approximately the dose required. In a few experiments calcium cyanide introduced into the generating chamber served as the source of HCN. Leaks in the canvas and framework were carefully tested for with benzidine-copper acetate papers, sensitive to HCN in a concentration of 20 milligrammes of HCN per cubic metre (Sherrard, 1928), and any leaks found were corrected. No doubt some loss occurred from diffusion through the large area of canvas but was readily compensated for by adjusting the rate of flow of the generating fluids into the generating box.

For the purpose of drawing off samples of air from the midst of the fumigated grain a dry glass tube filled with the grain was inserted into the bag as far as its centre. This tube was connected with short lengths of glass and rubber tubing through a gas washing bottle containing caustic soda solution to a series of aspirators. About 5 litres of air were aspirated for each determination of HCN concentration. The results of these chemical estimations are very approximate. The marked affinity of rubber tubing for cyanide gas was not realized at the commencement of these tests. It will be seen from the photograph that in the case of some of the connections the length of rubber used was sufficient to materially affect the figures. As a control sensitive benzidine-copper acetate test papers were employed in the later tests as a chemical indicator of cyanide penetration. Chief reliance, however, is placed upon the observed effect upon live rat-fleas (genus Xenopsylla) which as already pointed out, serve as extraordinarily sensitive indicators of the presence of small concentrations of hydrogen cyanide.

Varieties of Grains employed in Fumigation Tunnel Experiments.

		Grains per Gramme.	Grains per Cubic Centimetre × 10.
1	Rice, Milchard (Rangoon) ...	... 53	... 396
2	Rice, Malkora (Calcutta) ...	... 62	... 480
3	Rice, Muthusamba (S. India) ...	... 80	... 630
4	Green Gram (*Phaseolus aureus* Roxp.)	... 24	... 188
5	Ulundu (*Phaseolus Mungo* Linn.)	... 25	... 190
6	Ulundu (husked) ...	... 82	... 591
7	Kundu kadala (*Cicar arietinum* Linn.)	... 7	... 52
8	Bola kadala (*Pisum sativum* Linn.)	... 5	... 28
9	Dahl Kasauli (*Cajan cajan* Millspough)	... 52	... 350
10	Dahl Mysore	... 97	... 695

Mean circumference of bags, 52 inches.

Kundu and bola kadalas and green gram are more or less spherical in form. The rices have the familiar ovoid shape. Ulundu and the dahls have an oval shape flattened from side to side. Mysore dahl, the smallest of the grains, has a pinkish colour while Kasauli dahl is yellowish. It will be appreciated that the size and shape of the grain and its absorptive power for cyanide must have a great effect upon the penetrability of the gas into its midst. The sacks of grain were bought in the open market.

After each fumigation and subsequent ventilation the grain was emptied from the bags and spread out in thin layers in the open air and left till traces of cyanide could no longer be detected (usually within 24 hours under these conditions). After the tenth experiment a new lot of bags was brought into use to obviate any possible error due to change in the quality of the grain resulting from repeated fumigation. It was found that unopened bags newly delivered from the warehouses were somewhat less permeable to the cyanide fumes than bags that had been repeatedly emptied and refilled but not subjected to any form of compression.

These experiments were mostly carried out in July and August, 1929, during the south-west monsoon. Fumigation usually began at 2 P.M., mean temperature about 82°F., saturation deficiency 0·18 inches of mercury. An attendant was sent to the rat destruction pound about 8 A.M. each morning of the experiments to procure live rat-fleas.

The procedure as regards inserting fleas into the grain bags was identical throughout. The fleas themselves were introduced into special containers consisting of a cylinder of 400 mesh brass gauze, one inch in diameter and two inches long, with a loose cotton wool plug at each end. They seemed perfectly at home in this receptacle and their death-rate when thus introduced into the midst of an unfumigated grain bag and left overnight does not exceed that in a similar tube in a cupboard. When it was desired to test the effect of HCN on the ova or larvæ of fleas the original 3×1 or $4\times\frac{1}{2}$-inch glass tubes in which the fleas were brought to the laboratory were used as eggs and larvæ holders lightly plugged with cotton wool. By the time the tubes arrive at the laboratory most of the tubes show eggs adherent to the glass. It is necessary to keep eggs for about a week if a supply of nearly hatched larvæ is required. Loose cotton wool plugs are so permeable to HCN fumes surrounding the tubes that the lethal action observed on fleas and eggs inside plugged tubes of dimension $4\times\frac{1}{2}$ inch was practically the same as that in the gauze cylinders, whose permeability may be considered ideal.

The gauze cylinders or lightly cotton wool plugged tubes were placed in three situations in the rice bags :—

(1) Centre of central axis of bag.
(2) Half-way between centre and periphery of bag opposite.
(3) Within an inch of periphery of rice bag.

TABLE XIX.

Experiments on the Cyanide Fumigation of Grain in Sacks in a Fumigating Tunnel Connected to a Liston Cyanide Fumigator.—Parasitological Results.

Experiment No.	Mean connection of HCN parts per 100,000 in Circulating Air.	Time of Exposure of Grain to HCN Minutes.	Grain No.		Rice Milchard. 1			Rice Malkora. 2			Rice Muthusamba. 3			Green Gram. 4			Ulundu. 5			Ulundu (Husked). 6			Kundu Kadala. 7			Bola Kadala. 8			Dahl Kasauli 9			Dahl Mysore. 10		
					S.	M.	C.	S.	M.	C.	S.	M.	C.	S.	M.	C.	S.	M.	C.	S.	M.	C.	S	M.	C.	S.	M.	C.	S.	M.	C.	S.	M.	C.
X.	400 ...	30	Fleas	K	10	10	10	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	10	10	4
				S	0	0	0	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	0	0	**6**
XI.	250 ...	40	Fleas	K	6	12	6	6	12	6	6	12	6	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
				S	0	0	0	0	0	0	0	0	0	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
			Eggs	K	—	—	4	—	—	5	—	—	2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
				H	—	—	0	—	—	0	—	—	**3**	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
XII.	100 ...	30	Fleas	K	3	3	3	2	3	3	2	4	3	2	4	2	3	2	4	3	3	0	4	4	3	6	3	2	3	2	0	3	3	1
				R	0	0	0	0	0	0	0	0	**1**	0	0	**2**	0	0	0	0	0	0	0	0	0	0	0	0	0	**1**	0	0	0	**1**
				S	0	0	0	0	0	0	0	0	—	0	0	—	0	0	0	0	0	**3**	0	0	0	0	0	0	0	—	**3**	0	0	**1**
XIII.	250 ...	40	Fleas	K	3	3	3	3	2	4	4	9	4	9	3	4	3	7	3	3	3	0	3	4	5	3	3	3	—	—	—	5	4	3
				R	0	0	0	0	0	0	0	0	0	0	0	0	0	**4**	**3**	0	0	0	0	0	0	0	0	0	—	—	—	0	0	0
				S	0	0	0	0	0	0	0	0	0	0	0	0	0	—	—	0	0	**3**	0	0	0	0	0	0	—	—	—	0	0	0
XIV.	200 ...	60	Fleas	K	4	2	5	2	5	5	5	5	8	3	5	7	3	3	7	5	5	5	3	5	7	3	5	8	—	—	—	4	1	2
				R	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**1**	0	0	0	0	0	0	—	—	—	0	0	**1**
				S	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	—	0	0	0	0	0	0	—	—	—	0	**2**	**2**
			Eggs	K	—	—	6	—	—	5	—	—	4	—	—	4	—	—	4	—	—	3	—	—	5	—	—	4	—	—	—	—	—	0
				H	—	—	0	—	—	0	—	—	0	—	—	0	—	—	0	—	—	0	—	—	0	—	—	0	—	—	—	—	—	**4**
XV.	470 ...	20	Fleas	K	4	7	6	4	7	9	4	4	6	5	4	8	4	3	7	5	5	10	4	7	12	4	8	8	—	—	—	3	7	7
				S	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	—	—	—	0	0	0
			Eggs at C.	K	—	—	4	—	—	2	—	—	3	—	—	—	—	—	4	—	—	4	—	—	6	—	—	5	—	—	—	—	—	3
				H	—	—	0	—	—	0	—	—	0	—	—	—	—	—	0	—	—	0	—	—	0	—	—	0	—	—	—	—	—	0
XVI.	490 ...	15	Fleas	K	3	5	6	3	6	5	4	3	8	4	9	6	4	4	6	4	5	4	5	6	6	5	6	4	—	—	—	5	5	8
				R	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**2**	—	0	0	0	0	0	0	—	—	—	0	0	0
				S	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	—	**2**	0	0	0	0	0	0	—	—	—	0	0	0
			Eggs at C.	K	—	—	4	—	—	5	—	—	6	—	—	5	—	—	5	—	—	1	—	—	3	—	—	3	—	—	—	—	—	5
				H	—	—	0	—	—	0	—	—	0	—	—	0	—	—	0	—	—	**3**	—	—	0	—	—	0	—	—	—	—	—	0

XVII.	160 ...	40	Fleas	K	4	4	6	4	4	6	2	4	6	4	4	3	—	—	—	—	—	—	5	5	5	5	2	3	—	—	—	3	4	3
				R	0	0	0	0	0	0	0	0	0	0	0	**1**	—	—	—	—	—	—	0	0	0	0	0	0	—	—	—	0	**2**	**3**
				S	0	0	0	0	0	0	0	0	0	0	0	**2**	—	—	—	—	—	—	0	0	0	0	0	0	—	—	—	0	—	**3**
			Eggs at C.	K	—	—	4	—	—	6	—	—	3	0	0	1	—	—	—	—	—	—	—	—	4	—	—	3	—	—	—	—	—	0
				H	—	—	0	—	—	0	—	—	0	0	0	**2**	—	—	—	—	—	—	—	—	0	—	—	0	—	—	—	—	—	**2**
			Larvæ at M.	K	—	2	—	—	2	—	—	2	—	—	—	—	—	—	—	—	—	—	—	3	0	—	—	—	—	—	—	—	0	—
				S	—	0	—	—	0	—	—	0	—	—	—	—	—	—	—	—	—	—	—	0	0	—	—	—	—	—	—	—	**3**	—
XVIII	135 ...	30	Fleas	K	5	4	0	4	6	5	5	5	4	—	—	—	—	—	—	—	—	—	—	—	—	4	4	4	—	—	—	4	2	1
				R	0	0	—	0	0	—	0	0	**1**	—	—	—	—	—	—	—	—	—	—	—	—	0	0	0	—	—	—	0	**1**	0
				S	0	0	**4**	0	0	**2**	0	0	—	—	—	—	—	—	—	—	—	—	—	—	—	0	0	0	—	—	—	0	**1**	**4**
			Eggs at C.	K	—	—	4	—	—	5	—	—	3	—	—	—	—	—	—	—	—	—	—	—	—	—	—	4	—	—	—	—	—	0
				H	—	—	0	—	—	—	—	—	0	—	—	—	—	—	—	—	—	—	—	—	—	—	—	0	—	—	—	—	—	**5**
			Larvæ at C.	K	—	—	0	—	—	0	—	—	0	—	—	—	—	—	—	—	—	—	—	—	—	—	—	2	—	—	—	—	—	0
				S	—	—	**3**	—	—	**2**	—	—	**3**	—	—	—	—	—	—	—	—	—	—	—	—	0	0	0	—	—	—	—	—	**3**
XIX.	240 ...	20	Fleas	K	4	4	5	5	5	5	5	4	0	6	3	2	—	—	—	—	—	—	5	5	5	—	—	—	5	0	0	—	—	—
				S	0	0	0	0	0	0	0	0	**5**	0	**1**	**2**	—	—	—	—	—	—	0	0	0	—	—	—	0	**4**	**4**	—	—	—

Surface of Grain bags 1, 2, 4, 5, 6, 7, 8, 9, uniformly wetted with watering can. No. 3 kept dry as control.

XX.	260 ...	40	Fleas	K	2	2	5	4	4	4	2	4	4	3	5	6	3	4	2	3	4	4	4	4	5	2	4	4	4	3	2	—	—	—
				R	0	0	**2**	0	0	0	0	0	0	3	0	**1**	0	0	**2**	0	0	0	0	0	0	0	0	0	0	**2**	**2**	—	—	—
				S	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**1**	0	0	0	0	0	0	0	0	0	0	0	0	—	—	—
			Eggs at C.	K	—	—	4	—	—	6	—	—	6	—	—	3	—	—	3	—	—	3	—	—	6	—	—	4	—	—	3	—	—	—
				H	—	—	0	—	—	0	—	—	0	—	—	0	—	—	0	—	—	0	—	—	0	—	—	0	—	—	0	—	—	—

Surface of Grain bags 1—9 wetted with watering can.

XXI.	172 ...	60	Fleas	K	4	4	8	3	3	3	4	5	5	4	4	4	3	4	5	4	4	0	3	3	7	4	4	5	3	4	1	—	—	—
				R	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	—	—	—
				S	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**9**	0	0	0	0	0	0	0	0	**3**	—	—	—

A bag of Rangoon beans was employed in Experiment XXII. All fleas killed.

K=killed. R=revived on exposure to air. H=hatched out into larvæ.

TABLE XX.

Experiments on the Cyanide Fumigation of Grain in Sacks in a Fumigating Tunnel connected to a Liston Cyanide Fumigator.

Chemical Results.

Expenditure No.	Mean Concentration of HCN in Circulating Air.	Mean Time of drawing off Sample.	Hydrogen Cyanide concentration in four litres of Air drawn off from the centre of the Grain Bag parts per 100,000.									
			Rice Milchard. 1	Rice Malkora 2	Rice Muthusamba. 3	Green Gram. 4	Ulundu. 5	Ulundu (husked.) 6	Kundu Kadala 7	Bola Kadala. 8	Dahl Kasauli. 9	Dahl Mysore. 10
XI.	250	35	—	—	8	—	—	—	—	—	—	—
XII.	100	25	—	—	3	—	—	—	—	—	—	—
XIX.	240	10	8	10	4	4	—	—	12	—	2	—
XX.	260	35	—	—	4	—	—	—	32	—	—	—
XXI.	172	55	10	11	6	22	13	trace	35	54	trace	—
XXII.	115	45	—	5	—	—	—	—	—	—	3	—
		180	6	10	4	12	10	2	6	11	—	—
XXIII.	180	40	10	5	6	8	8	8	50	41	8	4
		80	26	7	9	18	45	9	34	70	9	2
XXIV.	198	45	3	8	6	18	36	12	81	26	12	—
		110	30	30	20	64	58	13	105	65	3	—
XXV.	500	110	45	55	45	110	130	15	—	170	35	—
XVII.	160	Benzidine acetate test papers at centre of bags of Malkora rice, Kundu Kadala, and Rangoon beans turned distinctly blue; papers at centre of bags 1, 3, 4, and 8 showed little or no effect at end of fumigation. Cyanided air aspirated at 30 minutes at depth of 4 inches showed 90 p.p.h. from Malkora, Kundu Kadala 40, Kasauli Dahl 5.										
XVIII.	135	Benzidine acetate test papers at centre of bags 1, 2, 3, 8 turned definitely blue; paper in centre of bag 10 only slightly blued.										

11.—Observations on Absorption of Hydrogen Cyanide by Grain in Sacks in Fumigation Tunnel.

Experiment (25).

Immediately after the conclusion of the two hour fumigation period employed in this experiment (HCN in circulating air 500 p.p.h.) the tunnel was opened without any preliminary ventilation. 250 gramme samples of milchard and muthusamba rice, husked ulundu, and kasauli dahl were spooned up from the surface of the freshly opened bag, placed in stoppered glass bottles, and removed forthwith to the laboratory of the Government Analyst. Determinations of the hydrogen cyanide absorbed were made as indicated below. The results exhibit the effect of high dosage with cyanide combined with lack of ventilation. The cyanide was allowed to diffuse out of the bagged grain before the second and third series of samples were taken in a similar manner. The high initial figures seem to point to condensation of the hydrogen cyanide on the surface of the grain.

Time elapsing since Cyanogas Treatment.

	2 Hours.	24 Hours.	72 Hours.
	HCN parts per million.		
	Series 1.	Series 2.	Series 3.
Muthusamba ...	4,430 ..	410 ...	18·0
Milchard ...	4,590 ...	911 ...	9·7
Ulundu ...	1,350 ...	394 ...	4·9
Dhal ...	4,792 ...	648 ...	11·9

The results shown are those for the acid distillation of 100 grams grain.

Experiment (18).

This experiment with a mean HCN concentration in the air circulating through fumigating tunnel of 135 parts per 100,000 of air and a half hour exposure was on similar lines to the above, but after the period of fumigation had expired pure air was circulated through the tunnel for another half hour. Surface samples of milchard rice were then removed to the Government Analyst's laboratory and analysed with the following results :—

		HCN parts per million.
Milchard 100 grams	Acid distillation ...	105

It should be realized that these results apply to rice grains situated just below the gunny bag exposed to the full concentration of HCN gas for the times stated. In Experiment XXV., using the abnormally high concentration of HCN in the circulation of 500 p.p.h., a relatively high concentration of HCN was attained even in the centre of the bag (See Table XX.).

In Experiment XVIII., however, the concentration of HCN and time of exposure approximated to that recommended for ordinary fumigating practice, and in this instance only just sufficient HCN reached the centre of the bag to definitely turn a benzidine copper acetate test paper.

V.—The Practice of Cyanide Fumigation.

1.—General uses of Cyanide Fumigation.

Coquillet, an officer of the United States Department of Agriculture, appears to have been the first to employ hydrogen cyanide gas for fumigation purposes, viz., the destruction of the scale insect pest of citrus trees, in 1886. As already indicated, its use for this purpose is now general wherever orange orchards are found. The trees are tented, liquid HCN liberated beneath the tent or calcium cyanide dust blown in.

Every year cyanide fumigation is increasingly applied to economic purposes, *e.g.*, green house fumigation, disinfestation of wheat from weevils, "bran bugs," and other economic pests of stored grain, destruction of burrowing animals, rabbits, moles, and field rodents generally, termites, land crabs, locusts, wireworms in soil.

The cyanide fumigation of ships, lighters, shore warehouses and other compartments, and in tunnels, and conveyors for the destruction of rats and their fleas requires special consideration for purposes of plague prevention.

2.—Fumigation of Ships.

Sulphur dioxide gas generated from a Clayton apparatus is the chemical most commonly employed by port authorities for ship fumigation, but it is gradually being superseded for this purpose by the more efficient, if more dangerous, cyanide gases.

The United States Quarantine authorities were the pioneers of cyanide fumigation of ships. The gas was first authorized in the United States Quarantine Regulations as a fumigant in 1910 and was used for anti-plague purposes in Porto Rico in 1912, and by the Cuban authorities at Havana in 1914. Since the outbreak of human plague at Naples in 1901 and the subsequent discovery of an extensive epizootic among the rats of the docks at Punto Franco, the Italian authorities have devoted much attention to de-ratisation of warehouses and ships. According to Lutrario (1928) the proportion of ships fumigated with HCN in Italy has constantly increased since 1921 (26 per cent.) and in 1926, 43 per cent. of the total were so fumigated, sulphur dioxide being employed for the remainder. HCN gas is being increasingly used for ship fumigation at Spanish and South American ports.

A great impetus to cyanide fumigation in Great Britain was given by the issue of the United States Quarantine Regulations of 1920 which required that all vessels engaged in trade with foreign ports should be fumigated not less than once in every six months simultaneously in all parts, thus complying with the recommendation to this effect of the International Sanitary Convention of 1912 (ratified in October 1920).

British shipping companies trading with the United States commenced experiments on ship fumigation with hydrogen cyanide gas, which were watched on behalf of the Ministry of Health by Messrs. Stock and Monier-Williams, to whose illuminating report the writer is particularly indebted for information on all aspects of ship fumigation.

Some of the largest Trans-Atlantic liners afloat, including the ss. "Mauretania" 30,700 tons, and the ss. "Berengaria" 52,700 tons have been succesfully fumigated with hydrocyanic acid gas. Fumigating operations of this magnitude, however, require elaborate preparations, while as Col. Reece has pointed out, the volume of poison gas disengaged in fumigating a single one of these gigantic vessels exceeds that liberated in any gas attack in the Great War.

The art and science of ship fumigation has been brought to the highest pitch of development by the New York Quarantine authorities. Attention is directed to the series of papers by Grubbs and Holsendorf, Akin and Sherrard (1928), and the note to the Committee of the Office International d'Hygiène Publique by Taliaferro Clark (May, 1928). According to the latter during the period July 1, 1926 to June 30, 1927, 20,284 vessels from foreign ports reached the United States and were submitted to inspection by the quarantine authorities. Of this number, 5,114 were fumigated for the destruction of rats. Nearly all these fumigations were effected after discharge of the cargo from the ship. 3,317 of these fumigations were carried out with hydrocyanic acid gas and the remaining 1,797 by means of sulphur dioxide gas.

Formerly before the introduction of improved measures for the rat-proofing of vessels 65 per cent. of the rat infestation was found in the holds and 35 per cent. in the superstructures of the ship. Now the position is entirely reversed, only 30 per cent. of the rats are found in the holds, irrespective of the nature of the cargo.

It will be appreciated that the problem of fumigating superstructures differs fundamentally from that of dealing with holds. The former is not affected by the state of the cargo. The effective fumigation of holds when full of cargo is difficult and is usually only attempted in the case of ships definitely known to be plague infected at the time; more commonly the cargo of such ships is discharged into lighters by stages and fumigation repeated after each stage, finally the cargo itself in the lighters is re-fumigated. The difficulty is to secure effective circulation of the cyanide gas and to remove it from pockets of cargo after fumigation.

In ordinary practice the cargo is discharged from the hold into lighters before fumigation commences, and under these conditions the proportion of rats killed to those recovered by subsequent trapping is very high.

The question of the effective fumigation of loaded ships with HCN gas is now engaging the attention of a Fumigation Commission of the League of Nations.

In America liquid hydrocyanic acid in cylinders seems to be the product most favoured for the fumigation of the holds of large ships at the chief quarantine stations, Zyklon B. or HCN discoids being used for the superstructure and for the whole ship at smaller stations.

Liquid hydrocyanic acid cannot be exported to the tropics in cylinders. It is available adsorbed in the "discoids" supplied by an American firm or the German product Zyklon B. which liberate a definite weight of HCN gas on exposure to air.

The Spanish authorities employ a special apparatus for generating HCN outside the ship. Sodium cyanide solution is run into strong sulphuric acid. The hot gas evolved is distributed from the fumigating launch to the various parts of the ship through flexible trunks with the aid of compressed air. No attempt is made at a continuous circulation through the fumigator as in the Liston machine.

The data in the following table taken from the report by Taliaferro Clark show the results obtained in the United States from ship fumigation :—

TABLE XXI.

Comparison of HCN with SO_2.

		No. of Ships treated.	No. of Rats killed.	No. of Rats captured after Fumigation.	Per Cent. efficacy of Fumigation.
	SO_2	62	747	223	77
	HCN	182	2,811	212	95
Superstructure of Ships	SO_2	32	133	107	55
	HCN	31	729	45	94
Empty Holds of Ships	SO_2	28	702	28	96
	HCN	34	854	9	99
Full Holds of Ships	SO_2	10	104	59	64
	HCN	10	80	20	80

From these figures the superiority of HCN over SO_2 is evident, particularly for superstructures ; SO_2 is really effective only for empty holds.

Reference may be made to appendices 2 and 3 to the report by Stock and Monier-Williams for an outline of the routine adopted for fumigation of ships at New York, and for a copy of the circular to Masters and Agents of vessels regarding fumigation at the port of New York and to the Memorandum issued by the Ministry of Health on the Fumigation of Ships with Hydrogen Cyanide (1928) and to recent notes on the same subject also issued by the Ministry containing particulars of the numerous precautions which must be adopted.

3.—Fumigation in Lighters : Experiments in Colombo Harbour.

For the reasons already given it is the customary practice to fumigate rat and flea infested or plague suspected goods in lighters rather than in the holds of ships.

The following paragraph is extracted from a report on "Fumigation of vessels from Plague infected Ports" U.S.P.H. Reports, Grubbs (1923). "Fumigation of cargo in lighters is not a difficult procedure. If closed lighters are available they should be sealed and fumigated in the ordinary way. If open lighters are used, the cargo should be covered with large tarpaulins to make a tent and cyanide generated underneath. To insure good results, the freight must be piled so as to leave air spaces and passage-ways for the circulation of the gas ; but this must be carefully confined by sealing all cracks in the covered lighters, or by fastening the tarpaulins carefully, especially to the deck. battening them down with reasonably heavy timbers or with boards with weights upon them."

This outlines the procedure adopted in the experiments in Colombo Harbour on the disinfestation of grain from rats and fleas, the results of which are set forth below. In experiments XXVIII. and XXIX. the conditions were purposely made adverse to gas circulation with a view to reproducing the effects of fumigation in lighter cargoes loaded without special supervision and extra apparatus to facilitate good distribution of the cyanide gas.

Fumigation in lighters was the method originally recommended by Dr. Marshall Philip, late Medical Officer of Health, Colombo, for dealing with grain imports to Ceylon.

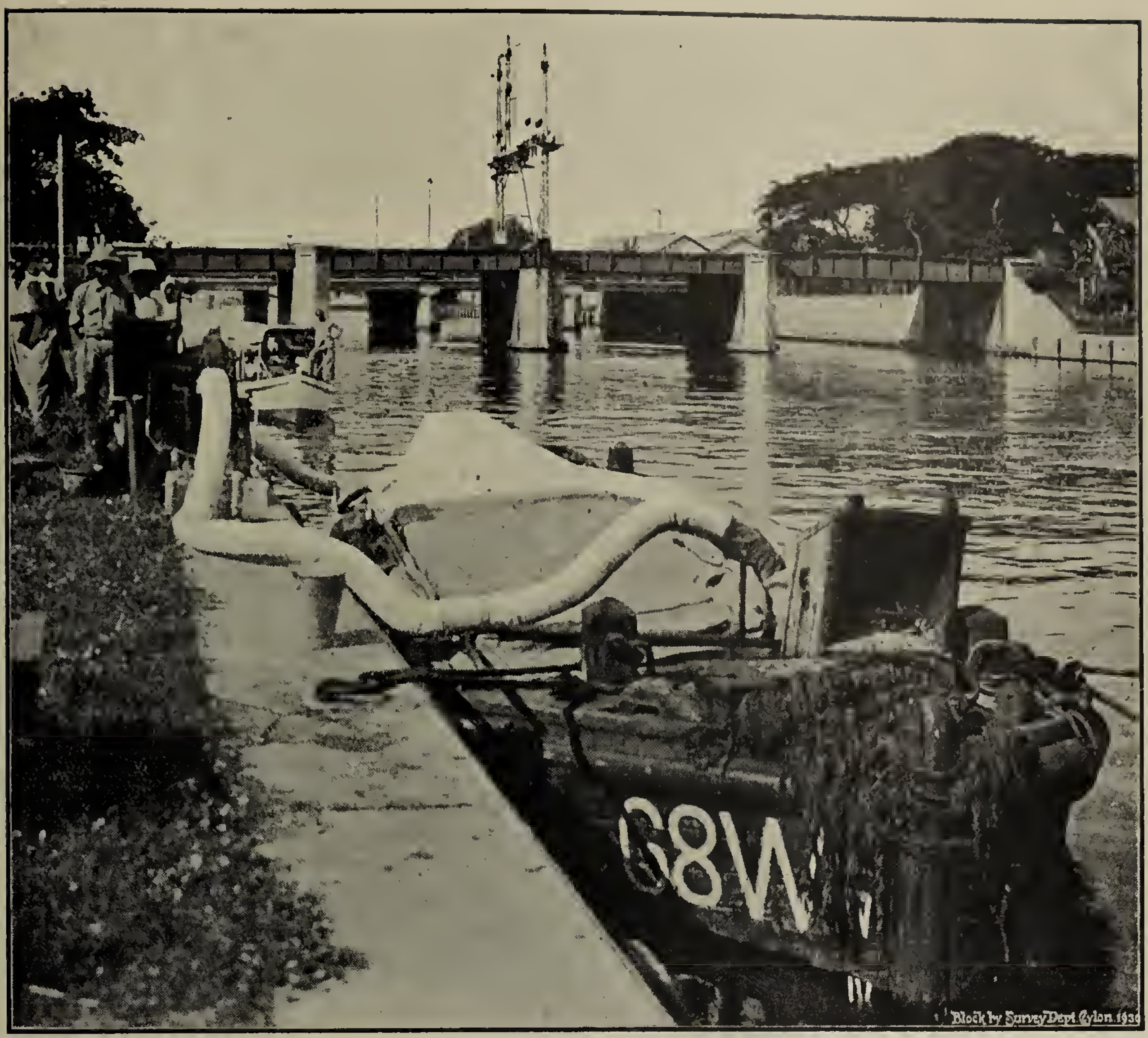
Three experiments on the disinfestation of lighters from rats and fleas by the cyanogen chloride dumping method have been carried out in Colombo Harbour, the first being conducted by the Director of the Bacteriological Institute, the second by the writer, and the third by the Port Surgeon in May and September, 1925, and April, 1926. In the first two experiments the lighters contained a few flea-holding bags of grain in which glass tubes lightly stoppered with cotton wool containing freshly collected rat-fleas were buried to a depth of about four inches and other tubes containing fleas and cages containing live rats were deposited at the ends, middle, and sides of the large lighters used. For the third experiment the lighter was fully loaded as per daily routine save for the space allowed for the dumping vessel.

The standard United States cyanogen chloride gas mixture used in these experiments was generated by dumping a cheese cloth bag holding the lumps of sodium cyanide and the sodium chlorate into a bucket containing the diluted hydrochloric acid placed at the bottom of the lighter opposite the middle of the hatch.

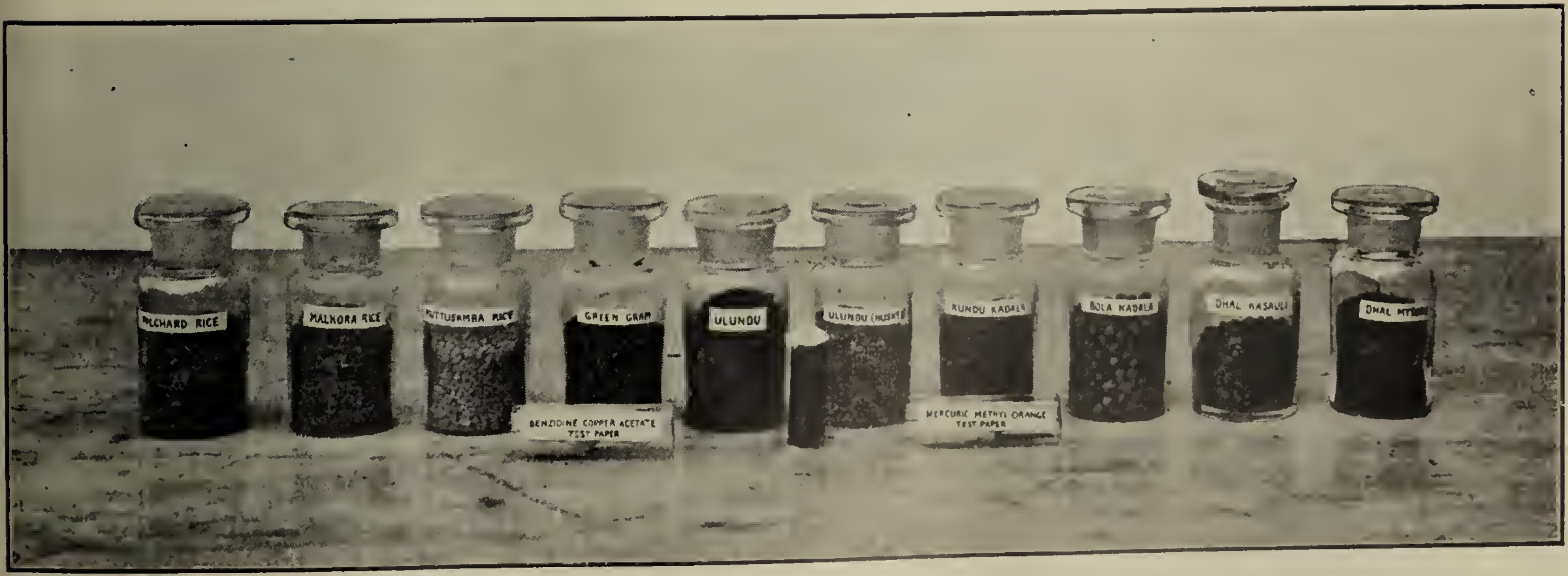
The following were the quantities of materials used per 1,000 cubic feet :—

Sodium cyanide	4 ounces	Hydrochloric acid	17 ounces
Sodium chlorate	3 ounces	Water	17 ounces

These amounts should generate about 0·94 ounce of cyanogen chloride gas and 0·33 ounce hydrogen cyanide per 1,000 cubic feet of air space and should suffice to kill an average adult rat in not more than ten minutes. (Cyanogen chloride in its pure form is only half as lethal as the same amount of hydro-cyanic acid gas).



LISTON CYANIDE FUMIGATOR CONNECTED TO SMALL LIGHTER CONTAINING 200 BAGS OF RICE.



SHOWING RELATIVE SIZE OF GRAINS USED IN FUMIGATION EXPERIMENTS. THE GAUZE FLEA-HOLDER AT CENTRE IS TWO INCHES HIGH.

The kill for both rats and fleas in the first experiment (time of exposure half an hour) and the second (time of exposure ten minutes only) was complete. A few cockroaches survived. These insects are capable of resisting a dose of cyanide at least four times as great as is fatal to fleas. The amount of materials used in the third experiment (exposure one hour) was inadequate for the complete disinfestation of the large 1,500 bag lighter used and the kill of both rats and fleas was incomplete. Nevertheless, some rats were killed in parts of the lighter remote from the generating point thus showing that good distribution could be achieved even in a fully loaded lighter of the largest size without special apparatus.

A Liston Cyanide Fumigator became available in 1929. Further experiments on the fumigation of grain in lighters were carried out with this apparatus, using it either as the source of HCN gas, or as a means of circulating gas generated in the lighter from calcium cyanide A. dust. The six-inch diameter delivery pipe from the generator was passed through a hole bored in the roof of the rearmost end of the lighter hold down to the floor of the lighter ; one of the rubber sleeves provided with the apparatus was used to render the roof joint airtight. The return pipe to the generator was connected to a similar socket let into the foremost end of the main deck of the lighter. Small holes were also bored in the fore-deck of the lighter to fit rubber corks through which long lengths of dry glass tubing connected with short pieces of rubber tubing were led to any desired situation with a view to connection to five litre aspirators on the deck of the lighter through a dilute caustic soda gas washing bottle. By titrating the soda with standard silver solution in the usual way the HCN concentration could be readily determined in the aspirated volume of air.

All these lighter experiments took place in the bay of the Harbour-Lake canal. The staff of the Government Harbour Engineer's Department co-operated. We are indebted to the Ceylon Wharfage Company for the loan of the lighters and to Messrs. Whittall & Co. for the loan of the rice fumigated.

Experiment (26).

Lighter capacity approximately 5,000 cubic feet including peak and stern quarter. A few rusty holes in the iron bulkheads permitted diffusion of cyanide gas into peak and stern quarters. Glass air sampling tube passed into fore part of hold to depth of four feet. Flea-holding rice bag placed on floor at centre of hold ; 14 fleas in two lightly wool stoppered glass tubes in grain at centre of bag ; 25 fleas in four tubes in grain at side of bag near surface ; live rats enclosed in canvas covered cages in centre and sides of hold and on each side of bulkheads together with flea-holding glass tubes. Gas generated from sodium cyanide and sulphuric acid in box of Liston machine was circulated through lighter continuously for half an hour. Concentration of hydrogen cyanide gas reached 245 p.p.h. At end of half an hour the exit trunk was disconnected from the lighter and air circulated for ten minutes. Fifteen minutes after opening up the lighter tests with live rats suspended on the hold and peak and stern quarters showed that it was safe to inspect the bag and test cages. A brisk breeze was blowing at the quay side.

All the 48 fleas in freely exposed tubes appeared dead. None revived. All 25 fleas in periphery of rice bag killed. One out of eight fleas in No. 1 tube in centre of bag showed signs of life on emptying out the rice, eventually three recovered. One out of six fleas in No. 2 central tube was active, three revived ultimately. All rats in the main hold were killed. The rats in the peak and stern quarters were unconscious but still breathing when withdrawn, they subsequently revived. Cockroaches were killed in great numbers. None were seen alive after fumigation. One *R. norvegicus* inhabiting the lighter was found dead in a corner.

Experiment (27).

The same lighter was used in the same way. The flea-holding rice bag was covered up with a pile of 12 others.

One tube of fleas in centre of flea-holding bag.
One tube of fleas six inches below top in central axis.
Two tubes of fleas four inches from surface.
Two tubes of fleas two inches from surface.

One canvas covered rat cage in midst of bags, others distributed as in previous experiments together with flea-holding tubes. Maximum concentration of HCN reached during one hour circulation of gas 232 p.p.h. All rats killed throughout lighter including peak and stern quarters. All fleas appeared dead on first inspection but four fleas in centre tube and one in centre top tube revived. Ten minutes' natural ventilation proved insufficient to clear lighter of poisonous fumes. Rats lowered into hold and stern quarters died rapidly.

Experiment (28).

New steel lighter capacity 2,000 cubic feet employed, fitted as in previous experiments. The writer was assisted in the determinations of the HCN concentration by Mr. Collins, the Assistant Government Analyst. The Government Analyst was also present. A barrier of 200 rice bags was stacked as closely as possible from floor to bottom in centre of lighter. A flea-holding rice bag, placed in the centre of this mass of grain, was loaded with glass and wire gauze flea-holders at depth of 2 inches, 4 inches, and centre of the rice. Flea containers were also placed between the rice bags and in various parts of the hold, peak and stern quarters. Rats were placed in canvas covered cages between bags and distributed with flea-holders about the lighter as in previous experiments. A glass tube connected through the wood battens of the deck to an aspirator was led into a rice bag adjacent to the central flea-holding one. A second aspirating tube enabled air to be drawn for determination of HCN concentration from the space between the bags 6 feet deep in the rice barrier. Mean concentration of HCN in air circulating in hold about 290 p.p.h. Period of cyanide gas circulation 135 minutes. At the end of this time traces of cyanide were detected in 5 litres of air drawn off from the central bag. The motor was stopped for 15 minutes during the circulation time to enable a repair to be effected.

The kill of rats and flea in the hold and peak quarter was complete. including all those in the central rice bag and those between bags. The stern bulkhead must have been gastight, since the rats and fleas below the after hatch were alive and active at the close of the experiment.

Experiment (29).

In this experiment the delivery trunk of the Liston fumigator was connected to a barrel placed in the hold of the same 2,000 feet lighter behind a similar barrier of 200 rice bags. A shallow metal cone was placed, apex upward, in the barrel the sides of which were perforated with numerous holes. The distribution of rats, fleas, and aspirator tubes was precisely the same as in Experiment XXVIII. Two pounds of calcium cyanide A dust from a freshly opened tin were tipped down into the barrel through the inlet trunk of the fumigator, the last bayonet-point being temporarily disconnected for the purpose and immediately reconnected. The dust spread out over the cone. The blower of the fumigator was then started up and air circulated in the usual manner. A bucket of water was emptied into the box of the fumigator to moisten the air to the maximum extent. After forty-five minutes the remainder of the 5-pound tin of calcium cyanide was dumped into the barrel.

The mean concentration of HCN in circulation was about 95 p.p.h. Circulation was continued till traces of cyanide appeared in air aspirated from the central bag, viz., 2½ hours. The kill of rats and fleas was as complete as before in the hold, inclusive of those in the innermost centre of the rice barrier, but rats and fleas in both peak and stern quarters survived.

Experiment (30).

A wooden lighter of about 2,200 cubic feet capacity was fitted with a bottom grid consisting of a series of stout wooden baulks set longitudinally with planks upon them crosswise about 6 inches apart. No attempt was made at a permanent fastening of the timber together. Such a temporary grid could be laid or taken up in a few minutes.

Two hundred bags of freshly imported Rangoon rice were placed upon this grid nearly filling the lighter. By this arrangement a space was provided underneath the load of rice for free circulation of the cyanide gas. The height of the grid above the bottom planks of the lighter was 15 inches. As usual, there was a little water above the keel. The ribs of the lighter projecting into the hold provided another 6 inches of lateral air space available for partial circulation along the sides of the rice bags.

A flea-holding bag was inserted in a position central to the whole mass of rice bags. It contained duplicate gauze flea-holders at surface, centre, and four-inch depths of rice, together with lightly stoppered 3 × 1 tubes holding freshly prepared benzidine-copper acetate and mercuric-methyl orange test papers. Rats and flea and egg holding tubes were scattered about the barge, in amongst the rice bags, and in the peak and stern quarters with tubes of cyanide test papers placed alongside them. The Liston Cyanide Fumigator was connected up as before but no air samples were aspirated from inside the lighter. Double tarpaulins were used on this occasion. The circulation period was 50 minutes and the mean dose of HCN in the delivery trunk 450 p.p.h. The kill of fleas, flea-eggs, and rats was complete throughout the lighter and the central flea-holding rice bags, while the tint of the test papers in the centre of the rice bag indicated effective penetration of HCN.

4.—Fumigation in Warehouses and other large Buildings ashore.

In January 1914 the writer witnessed an experimental disinfestation of a packed grain store by Glen Liston by means of his newly-devised cyanide fumigator. This successful demonstration took place before the members of the All-India Sanitary Conference at Lucknow.

Lutrario (1928) alludes to the large scale fumigation of the grain godowns at Venice with hydrocyanic acid gas in 1919. Their capacity was over 12 million cubic feet and they contained 250,000 quintals of grain. The gas was generated from sodium cyanide and sulphuric acid and the results were reported to be excellent. There was an epizootic of plague among the rats at the time.

If the roofs of the Chalmers Granaries or Manning Markets in Colombo are tarpaulined, there is no difficulty in fumigating completely partitioned compartments. No apparatus whatever is required. Passages should be left between the tiers of rice bags along which the calculated quantity of cyanogas dust, HCN discoids, or Zyklon B. is rapidly sprinkled immediately before closing and sealing the doors. The operator should wear a box respirator. After allowing the liberated HCN to act for some six hours the roof tarpaulins are removed and the doors opened the following morning. After a suitable interval a masked operator tests the interior for safety with cyanide papers and live rats. Complete disinfestation of the bagged rice from rats and fleas can readily be effected by this simple means. It would not cost an exorbitant sum to disinfest an entire plague infected set of granaries or to control the rat population by periodic fumigations.

HCN discoids were successfully used for an experimental disinfestation of compartment 102 at the Chalmers Granaries in 1930 using the equivalent of 2 ounce of liquid HCN per 1,000 cubic feet. The kill of rats in a 40,000 cubic feet store containing some 2,000 rice bags was complete in all parts. In this instance the air of the compartment was respirable within half an hour of opening the doors, nearly all the HCN having diffused out through the roof crevices during the night.

It is now the recognized practice to fumigate jails and hospitals of the largest size with the cyanide powders, for the destruction of bed-bugs. It is undoubtedly the best available method, but the fumigation frequently requires repetition as all the reproductive forms of the parasite are not always destroyed in one operation.

5.—Fumigation in Special Compartments.

A compartment for the cyanide fumigation of imported seeds has been installed in the Harbour premises for many years. It operates successfully at atmospheric pressure. At the quarantine station in New York specially constructed fumigating chambers are employed for the disinfestation of the lousy or flea infested clothing of immigrants into the United States. Either the generation method or liquid HCN is used in high concentrations. In order to assist the penetration of the hydrogen cyanide gas into the interior of the sacks of clothing an initial vacuum equivalent to 26 inches of mercury is set up. The time of exposure is 30 minutes for clothes and one hour for baggage. After fumigation the sacks of clothes are suspended in a current of air till the odour of the gas has disappeared.

Apparatus of similar design is also employed by the Australian authorities, a 15° vacuum is obtained in the chamber (see Appendix 5 of the report by Stock and Monier-Williams, 1923).

An initial vacuum may be considered essential for the complete disinfestation of relatively impermeable materials.

Cyanide fumigating chambers are also employed at nearly all inland stations on the Russo-Polish frontier for disinfestation of the clothing and baggage of refugees. Similar stations are in use along the Holland frontier.

6.—Railway Fumigation.

Hydrogen cyanide gas was first used for the destruction of vermin in the sleeping carriages of the Cape Government Railway as far back as 1898. The method has been adopted by many railroad authorities since. At Warsaw a tunnel was constructed in 1920 capable of holding several railroad cars. The ends are hermetically sealed before introducing the cyanide gas.

7.—Large scale Cyanide Fumigation of Grain with the aid of Mechanical Conveyors.

For economic reasons it may be necessary to store grain, such as wheat and corn, in the storage elevators for as long a period as one to two years. During this period the grain may suffer considerable loss and damage from the activities of a variety of insects. According to Schenk (1926) the principal species responsible for the losses sustained in the United States by such depradations are the granary weevil, *Sitophilus granarius* L, the rice weevil, *Sitophilus oryza* L, the confused flour beetle, *Tribolium confusum* Fab., the rust red flour beetle, *Tribolium* (*castaneum*) *ferrugineum* Fab., the saw-tooth grain beetle, *Silvanus surinamensis* L., the flat grain beetle, *Crypturgus pusillus* Gyll, (*Laemophoeus minutus*), the lesser grain borer, *Rhyzopertha dominica* Fab., the Angoumois grain moth, *Sitotroga cerealella* Oliv., and the Cadelle, *Tenebroides mauritanicus* L.

The activities of these insects, when numerous, may cause a rise of temperature of the stored wheat, necessitating aeration by transference to fresh bins. The shrinkage in weight resulting from the consumption of the grain by these insects may reach 10 per cent of the original. The breaking up of the kernel reduces the grain to a lower economic grade. Moreover, the proportion of flour obtained by milling wheat may be reduced from 65 per cent. or 75 per cent. to 40 per cent., owing to the action of certain grain insects on the carbohydrate portion the kernel.

It will be realized from the foregoing that insect infestation of grain is an economic problem of the first magnitude, quite apart from plague prevention, loss of vitamin content, or other hygienic considerations. Till recently carbon disulphide has been the fumigant chiefly employed for the economic disinfestation of grain, but it has the great disadvantage of being inflammable and it may impart an objectionable odour to the grain. After a preliminary series of experiments with liquid hydrocyanic acid, the American Cyanamid Company adopted the method of distributing a calcium cyanide product, Cyanogas G, evenly throughout the bin requiring cyanide fumigation. Experiments on the large scale fumigation of wheat by this method were undertaken with the elevators of a large company at Kansas City. Wheat was brought to the head of the bin by a travelling belt at the rate of some four to six thousand bushels per hour. The cyanide powder was added in the requisite proportions by means of a specially designed electrically driven hopper directly into the stream of wheat as it poured through a canvas covered chute into the bin.

The kill was determined on insects ensconced in perforated cardboard boxes. The fumigating period varied from one to seven days. The dosage recommended as a result of these elaborate experiments was 25 pounds of cyanogas G per 1,000 bushels of wheat, and the fumigation period 72 hours. The insects were killed both in the mature and immature stages of their development. Even after 24 hours there was sufficient cyanide gas left in the wheat to stupefy live weevils introduced into it, but by admixture with untreated wheat the concentration of the residual fumes would be lowered to an ineffective level. Hence the decision to keep the grain three days in contact with the fumigant. The general conclusions were reached that after cyanide fumigation of grain by this method it has no objectionable odour, that the amount of residual HCN is insignificant, and that neither the germinating power, quality or baking properties of the milled flour are adversely affected.

8.—Note on Cyanide Fumigation of the Burrows of Rats and Miscellaneous Field Rodents.

Calcium cyanide is now extensively employed for rodent destruction in burrows, the method of generation of HCN by simple exposure of the powder to air being much more convenient than the use of acid and cyanide solutions together with an elaborate equipment of pipes and ducts for the introduction of the generated gas from a special machine (Goré, 1925). The powder must, however, be well distributed in the burrow. Goré showed that the mere sprinkling of the calcium cyanide powder into the mouth of the rat burrow was inadequate to effect a satisfactory kill in an elaborate system of burrows with branches leading off from the main channel. It suffices for ground squirrels and other animals with simple burrows. The powder in the form of A dust should be blown throughout the system of burrows by means of a foot or hand pump. The method has been extensively employed for the destruction of rabbits in Australia. Cyanide dust is blown into the warren at one opening till it begins to appear at others, these are then blocked up and finally the entrance treated. Blowing operations are conducted from the windward side to prevent the breeze blowing back the dust.

The destruction of rodents by this means may be recommended to sanitary or agricultural authorities in Ceylon whenever the services of intelligent operators are available. Sulphur dioxide is a safer fumigant for this purpose in the hands of coolie labour. With proper supervision, however the risk is negligible. Calcium cyanide dust has now been used daily for a considerable period in this laboratory by the attendants for the destruction of rats without any discernible ill effects upon their health.

VI.—Economic Aspects of Various Methods of Grain Disinfestation.

1.—SHIPPING.

The importation of plague with grain from overseas might be prevented by fumigation of the cargo in the ship as soon as possible after arrival. Unfortunately the rat population of the superstructure of a ship is not, as a rule, isolated from that inhabiting the holds. Fumigation, therefore, must extend to the whole ship entailing the complete evacuation of all passengers and crew. As Colombo is not a terminal port for most ships bringing grain, and as many such ships carry passengers to Europe from other Eastern ports, it is obvious that fumigation on shipboard would be highly inconvenient and costly, though it would, perforce, have to be adopted if the ship was proved to be actually infected with plague. Even so, in the case of unratproofed ships, the bulk of the cargo would have to be discharged and fumigated in lighters before completing the fumigation of the ship itself.

It should, however, be possible to effectively isolate the holds of ships regularly engaged in the Eastern grain trade, to abolish all dead spaces capable of sheltering rats from the action of a fumigant, and to so arrange the stacking of the rice bags that fumigation of the whole consignment could be carried out with an economical quantity of cyanide powder at sea or immediately after reaching port. Special holds of this type would naturally be fitted with a permanent motor aerothrust for the rapid displacement of the cyanide impregnated air as soon as possible after the completion of fumigation. The writer understands that a proposal of this sort has been seriously considered by a well known expert for practical application to the Rangoon-Colombo rice trade. The suggestion has been tentatively put forward that the fumigation of large consignments of grain should be carried out on the high seas by a specially trained staff employed by the Governments concerned.

It is certainly of the utmost importance that more effective steps should be taken to rat-proof ships engaged in commerce between Eastern ports on the same lines as those which have already proved so effective on the Atlantic routes. The requisite expenditure is amply justified on economic grounds alone.

The following official pronouncement on the subject is extracted from page 1064 of the International Public Health Year Book for 1928, issued by the Health Organization of the League of Nations :—

Plague : Rat-proofing of Vessels.

"After several years of experimentation and study, quarantine officers of the Public Health Service became convinced of the practicability of rat-proofing vessels, and this fact was actually demonstrated in New York in 1924. In that year, a large passenger vessel was chosen for demonstration purposes, and observation and trapping were carried on with the work of rat-proofing. As the work proceeded, the number of rats decreased, falling to nil."

"The response to the practical demonstration has been prompt and extensive, as shown by the rapid increase in the demand for such work from the shipping interests. During the year ended 30 June, 1926, 74 vessels have been surveyed in the port of New York for rat-proofing and work had actually begun on 26 of them. During the year ended 30 June, 1927, 152 surveys of vessels had been completed, and satisfactory progress in rat-proofing was under way on 82 vessels. The War Department has initiated this work on vessels of the Transport Service, and the Navy Department has become interested in it. Representatives of several foreign countries have visited the New York Quarantine Station for conference or demonstration."

"The rat-proofing of vessels, though essentially a public health measure, is important to owners from the standpoint of economy alone, both in the avoidance of a considerable loss to valuable cargo and to stores which are eaten and damaged by rats, and in quarantine exemptions. It is principally because of this economic appeal that the rat-proofing of vessels is meeting with such success."

2.—LIGHTERS.

As already explained, the cyanide fumigation of plague suspected cargo is usually carried out in lighters or barges.

There would be no need to seek any alternative method for dealing with grain imports to this Island were it not for the vast scale of the trade, the shortage of lighters and dockside space, and the difficulties arising out of any delay in discharging the lighters into the warehouses. As shown in Table I. the total quantities of rice imported in 1927 amounted to no less than 9,097,240 cwt., or 6,183,695 bags, in addition to 935,530 cwt. of other grains and forage. It has also been shown that consignments of grain from overseas ports are liable to vary enormously in regard to their potential danger *qua* the transference of plague infection, according to port of origin, plague state of the port, rat and plague state of the ship, and other factors. If all grain imports are subjected to routine fumigation provision must be made for dealing with 30,000 bags per diem. A single ship may bring 100,000 bags of rice. Any interruption in the normal rate of discharge from ship to sorting warehouse tends to disorganize landing operations. Hence if fumigation is to be carried out in lighters it is essential that the time consumed by the process should be reduced to a minimum.

The results of the experiments with lighters described in the preceding section indicate that if a simple detachable timber grid were placed at the bottom of each lighter in order to promote circulation of the fumigant, the bags were suitably stacked in the lighter, and the aim

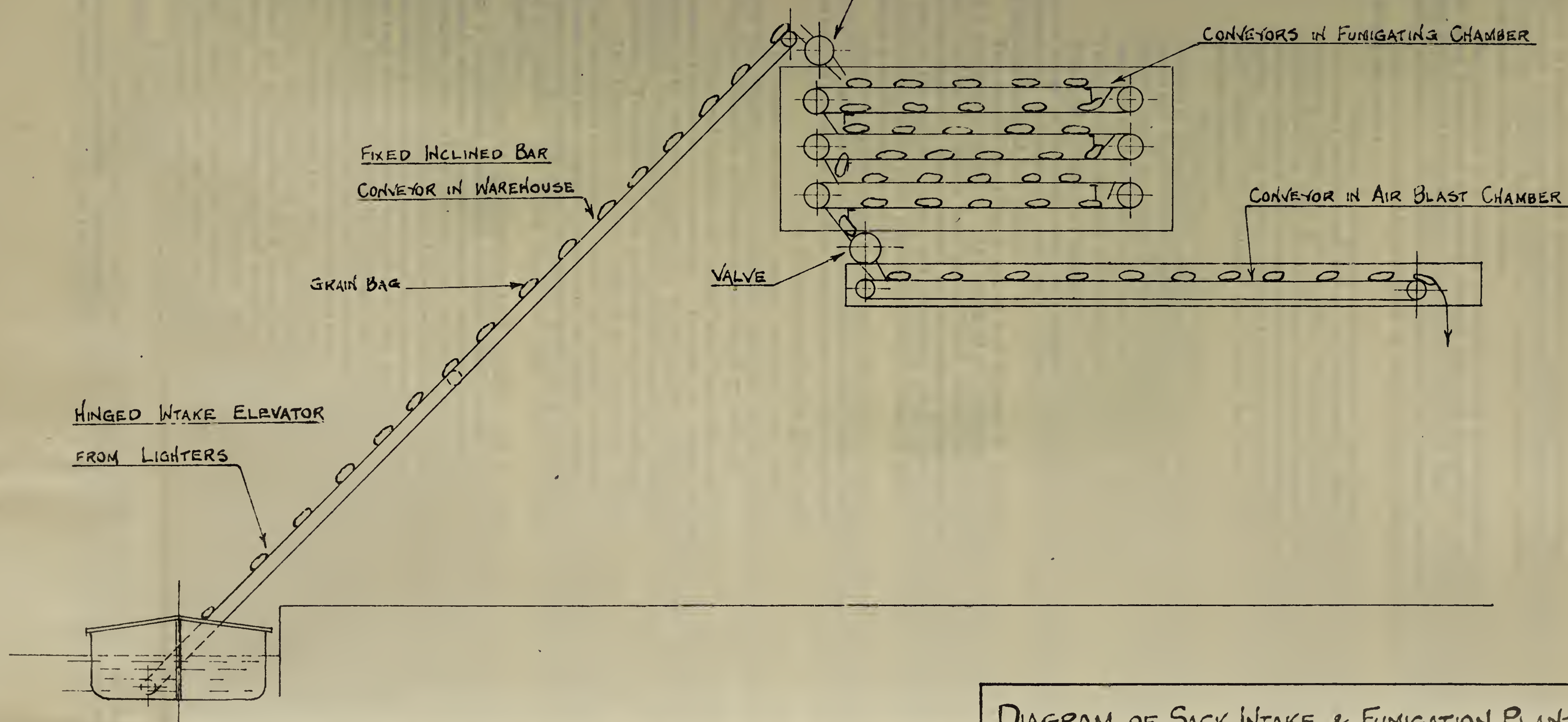


DIAGRAM OF SACK INTAKE & FUMIGATION PLANT FOR COLOMBO

restricted to obtaining pulicidal penetration of cyanide gas into the bags to a depth of 4 to 6 inches, then the time of exposure to a practicable dose of the fumigant could be reduced to about one hour with rice ; say one and a half hours for the complete operation including preliminary preparation and ventilation to disperse the fumes.

Gas generated in a common fumigator could be led through six-inch flexible trunks to two or more lighters and circulated through them as described in the lighter experiments. An electric drive would be preferable to a petrol motor for the fans. A continuous circulation of gas through the lighter for the whole fumigation period will probably turn out to be unnecessary.

The procedure would be somewhat as follows—using a fumigator fitted with twin delivery and return gas trunks :—

> Suppose four lighters were moored on each side of a jetty and four fumigators were placed between each pair in the jetty centre. The opposite pairs of lighters having first been tarpaulined and provided with inlet and exit points for the gas trunks would be connected up with the fumigators—a matter of moments—the generator started and the fan run full speed for fifteen minutes, thereby circulating the gas throughout all parts of the lighter. Within twenty minutes of their arrival at the quay all eight lighters would have been charged with fumigant, after which the fans could be run at reduced speed or stopped altogether.
>
> The next step would be to disconnect the exit trunk from the fumigator and run the fans at full speed for another quarter of an hour, thereby blowing out the cyanide fumes and ventilating the lighters sufficiently to enable them to be safely opened. The lighters could be prepared when approaching the quay so that the whole process at the quayside need not take, at the most, more than an hour and a half for eight lighters.

The cost of the proposed jetty fumigators would be inconsiderable.

Fumigation of goods in lighters is an elastic as well as a well tried method. Either the whole or a part of the grain could be fumigated to any extent desired in accordance with the epidemiological requirements of the day. Thirty-two lighters of the largest size could be dealt with simultaneously at four jetties.

The average grain bag is not so well exposed to the fumigant in a lighter as it would be in a fumigating conveyor. The result of the Colombo experiments indicate, however, that cyanide circulation between bags under forced draught in a fully loaded lighter is better than might be expected. Much depends on the method of stacking the bags, by sacrificing about 10 per cent. of the lighter capacity and employing simple devices for ensuring good circulation of the cyanide gas, fairly good penetration into the bags of grain may be secured throughout the lighter in a surprisingly short time.

Since the lighters could be brought to the quays covered and ready for fumigation there would be no possibility of a plague rat escaping ashore before fumigation was complete. This risk enters into all schemes in which an open lighter is brought alongside a fumigating plant on land.

3.—Fumigating Grain Elevators.

The tunnel experiments already recorded were carried out with a view to obtaining data for the construction of a fumigating conveyor for the uninterrupted transportation of sacks of grain from lighter to warehouse in a stream of cyanide gas.

If it proved feasible, this method would save time and labour since it would both fumigate and convey the rice in one operation. It should be clearly understood, however, that a large proportion of the imported plague fleas would transfer themselves to any rats that happened to be in the lighter. Fumigation of grain in hooded conveyors, therefore, is not a complete solution of the problem. The empty lighter would also require disinfestation.

The fumigation of empty lighters is a very simple operation, and the fumigation period need not exceed ten minutes. It would be possible to expedite the process by dropping a gas-tight cover with gas circulation leads over the lighter, pumping in a heavy charge of cyanide gas, and immediately towing away the lighter from the point opposite the fumigating plant to make room for another. The cover could be lifted after ten minutes and sent back along an overhead wire.

The advice of specialists has been obtained and it would appear that it is possible to design a mechanical fumigating conveyor which would give each bag an exposure to a dose of cyanide adequate to ensure complete pulicidal penetration of a bag of malkora, milchard, or muthusamba rice. If, as proposed, the rice were elevated from the lighters to a new overhead sorting warehouse situated in the Lake-Harbour canal, opposite the Chalmers Granaries, it would be necessary to construct a chamber at the upper end of the primary elevator in which the stream of rice bags could be carried to and fro till the required exposure time had been reached. The results of the tunnel experiments indicate that a half-hour exposure to a current of air containing 2 ounces of hydrogen cyanide per 1,000 cubic feet should give sufficient penetration for the purpose in view. These experiments were carried out at a mean atmospheric temperature of about 82°F. There is evidence that the rate of penetration of HCN gas into materials in sacks might be considerably accelerated and the time of exposure shortened by raising the temperature of the cyanided air in circulation in a fumigating conveyor to about 100°F. A further period of movement in a ventilating chamber would be required before the bags could be safely discharged upon the sorting floor of the warehouse when they would be conveyed mechanically to granary, railway truck, or cart, after an adequate period for further ventilation to get rid of cyanide fumes. The bags would enter and emerge from the fumigating conveyor through a revolving gas trap. Designs for such a plant are already available.

A to and fro 30 minutes fumigating conveyor capable of dealing with all imported rice is estimated to cost £68,000.

It would be necessary to take special precautions against the escape of rats from the lighters during unloading. This might be achieved by a system of electrical rat guards after the pattern devised by Taylor and Chitre (1923.)

As an alternative to the use of a special fumigating conveyor, disinfestation on the floor of the upper storey of the proposed grain elevator might be considered. If the grain were suitably stacked, two hours' exposure to a concentration of 150 p.p.h. HCN should amply suffice to kill not only the imagines but the eggs, larvæ, and pupæ of all rat-fleas in the midst of the grain. Ventilation could be carried out overnight and would be facilitated by the use of powerful exhaust fans in the roof. The cyanide gas could be generated without apparatus by simply sprinkling a cyanide powder in the alleyways between the rice stacks immediately before shutting the doors of the gaslight section under treatment. This method, however, would not be nearly so economical in fumigant as the conveyor.

These proposals for fumigating in conveyors and special warehouses integrate with the wider scheme now under consideration by the Port Commission for the modernization of the methods of transporting rice from lighter to granary. At present most of the rice is brought ashore by cooly labour into the quayside warehouses, sorted according to grade and mark for a number of consignees, loaded into bullock carts, and then across the road into the premises of the Chalmers Granaries where it is once more carried on the backs of coolies into the compartments leased by the various wholesale merchants.

Against the high initial outlay required for grain elevators of modern design should be set the considerable saving in transport charges per bag of rice delivered. The nett economy obtainable under this head would, probably, be many times greater than the additional cost of fumigating all imported rice.

Fumigation is not the only means of ridding grain of fleas. If it were economically feasible, storage for a sufficient length of time in absolutely rat-proof chambers would starve out the adult insects. The storage period would depend on the temperature and humidity of the air. About one week would suffice at average Colombo temperature to kill off nearly all fully developed fleas. The immature stages would require much longer, so that storage alone would be much more effective in freeing grain from flea-borne plague infection than from *cheopis* infestation. Under present conditions it is not practicable to solve the problem by storage alone. Though much of the grain is already stored for the requsite length of time in partially protected Government granaries a large proportion of the rice imported is railed direct to destination from the wharf, after passing through the transit sheds in the Customs premises. It would be necessary, therefore, not only to provide additional really rat-proof storage but to control the deliveries of the grain from both the old and new stores. The cost of such measures is difficult to estimate but would greatly exceed the most extravagant proposals for fumigation. Nevertheless it should be remembered that, apart from fumigation, every improvement in rat-proofing grain stores and each day's delay in delivery from rat-proof stores helps very materially to reduce the risk of transferring plague fleas. Each successive step in the transference of grain is associated with a rapid reduction in *cheopis* infestation from about 60 per cent. in the harbour transit grain sheds to about 30 per cent. in the Pettah wholesale granaries to about 8 per cent. in the main markets and still less in the small boutiques. Each handling of an infected consignment must involve a marked loss in plague fleas sheltering in the gunny bags. Hence the special value of rat-proof storage in in the initial stages of distribution of imported grain.

Grain infested with weevils and other economically injurious insects is treated on a large scale in America by the exposure for a few minutes in revolving cylinders or drums to a temperature of from 125°F. to 140°F. All stages of the insects are killed off by this degree of heat without affecting the germinating power of the grain.

Grain can also be disinfested by free exposure to a hot tropical sun. In Colombo, for economic reasons, imported grain must be dealt with in sacks, hence methods depending on heat alone cannot conveniently be employed.

VII.—Plague Preventive Policy.

The various stages in the transit of plague suspect goods from their overseas source to their ultimate destination in Ceylon may now be briefly reviewed from the plague preventive point of view.

The incidence of plague in the two chief sources of infection, Rangoon and Bombay, has markedly declined of recent years. Improvements to the cotton export warehouses at Bombay and the premises of the Port Comission at Rangoon have greatly reduced their rat population. It has to be remembered, however, that less than 20 per cent. of the huge Burman rice exports pass over the improved quays at Rangoon and that plague is also endemic at the rice exporting port of Bassein. Lighters that are far from being rat-proof convey the bulk of the rice from excessively rat-infested mills mostly situated along outlying creeks to ships lying in the Rangoon river.

It is the plague state of these rice mills and river lighters, therefore, that is of greatest interest to importing countries receiving the three million tons of rice annually exported from Burma. A vivid light has recently been thrown upon this question by the results of the rat-flea survey so well organized and carried out by Lieut.-Col. Jolly. Unfortunately the recent decline in the epizootic has prevented equally informative data being obtained regarding the distribution of plague among the five chief rodent species inhabiting the Rangoon foreshores. There is evidence that the mole rats (*Gunomys bengalensis*), which form 22 per cent. of the total rodents trapped and which carry most of the fleas collected in the rice mill survey, are comparatively little affected with plague. These mole rats bear 92·3 per cent. *X. astia*, a flea which is not only a less dangerous carrier of plague than *X. cheopis* but seems to be less readily transferred overseas. Probably, therefore, the high gross rat and flea infestation of the Rangoon rice mills and stores can be discounted to some extent *qua* danger of transference of plague infection. On the other hand the species *R. concolor*, *R. rattus*, and *M. musculus* forming 49·6 per cent. 5·2 per cent. and 20·8 per cent. of all rice mill rodents all carry a preponderance of *X. cheopis* and are all subject to severe epizootics of plague. In Rangoon city, the mole rats and *R. norvegicus* are outdoor species carrying a large proportion of *X. astia* while *R. concolor*, *R. rattus*, and *M. musculus* live mostly

indoors and the majority of their fleas are *X. cheopis*. It seems reasonable to conclude that the danger of exporting plague from the Burma rice mills mainly depends on the severity of the *concolor-rattus* epizootics in the stores annexed to these mills.

It is suggested that if a continous rat plague survey of these mills and the lighters alongside could be carried out the results would be of considerable value to rice importing countries, such as Ceylon. They might serve as a guide to the choice of consignments requiring fumigation with cyanide gas. Rice from an infected store should, preferably, be fumigated in lighters at Rangoon before shipment or alternatively at the port of entry before delivery to the consignee.

Norman White (1923) pointed out in his League of Nations Report that "The elimination of the rat from the rice mill and the rice store in Rangoon is, of course, the end at which to aim. If that were accomplished the plague problem of Rangoon might find a ready solution, a consummation which would be to the infinite advantage of Rangoon trade and commerce."

Judging from what the writer saw during his recent visit to Rangoon, it does not appear that much progress has been made in this direction since 1923. Perhaps, as Major-General J. D. Graham (1927) suggested in his Calcutta address on International Quarantine problems, more will be done when India ratifies the International Sanitary Convention of 1926.

The rat-flea state of the Rangoon lighters is still under investigation. If effective control could be obtained over the 4,700 odd lighters engaged in conveying rice to the ships it might be possible to considerably reduce the number of rats harboured by removing all skirting boards from the holds and to fumigate those in regular use on the same lines as in Colombo.

It is difficult to exaggerate the importance of adequate attention to the rat-proofing of ships engaged in the grain trade between Eastern ports. The following resolution was passed at the Plenary Session of the eighth Congress of the Far Eastern Association of Tropical Medicine, December 13, 1930 :—

> "This Congress is of opinion that the most permanent, reliable and economical method of preventing the transfer of plague from port to port through the agency of shipping lies in the rat-proofing of vessels and considers this method should take precedence over all others."

As already indicated such rat-proofing has proved a business proposition in the Western Atlantic trade and there seems to be no reason why it should not be equally successful on the far more plague stricken Eastern routes with their higher *cheopis* ship rat infestation.

Colombo is not a terminal port, hence comparatively little ship fumigation can be undertaken. At present ships docked in Colombo Harbour are partially deratized by fumigation of empty holds with sulphur dioxide gas generated from a large Clayton apparatus. The burden of carrying out the active deratization operations required to bring shipping along Eastern routes into conformity with Article 28 of the International Convention of 1926 would normally fall upon Bombay, Calcutta, and Rangoon. It may be pointed out, however, that it is to a large extent a waste of effort to fumigate empty ships at Rangoon and then load up with rice from rat infested lighters.

Routine fumigation of all ships from plague infected ports has now been abandoned by the American authorities. The rule both at Liverpool and New York is to thoroughly fumigate only those ships found on inspection by an expert staff to show signs of excessive rat infestation, or dead rats or other evidence of plague infection. At New York only about 10 per cent. of the ships arriving at that port show more than 30 rats and these are regarded as the potentially dangerous vessels. The inspection of a ship with a view to guaging the degree of the rat infestation by counts of droppings, nests and other indications is a highly technical procedure which needs special training and experience if the results are to be taken as reasonably accurate (Pierce 1930.) The permanent Health Officer at Rangoon has undergone a course of training at Liverpool in the technique and in his turn trained a special gang. It is obviously desirable that Colombo, also, should have the services of a permanent Port Health Officer expert in all such matters and assisted by an expert staff.

All Indian ports at present use sulphur for ship fumigation, but there can be no doubt that the cyanide process is much more efficient, especially for the ship superstructure, and now that cyanide products are available which greatly simplify the *modus operandi* the time seems ripe for its general adoption. Health Officers, however, are chary of any cyanide process on account of the danger to the lives of careless opeartors under their charge. The suggestion put forward by Dr. C. G. Crow, the well known Port Health Officer, Rangoon, that cyanide fumigation in such ports as Rangoon, Colombo, and Singapore should be carried out by a fumigation company under official supervision seems to merit careful consideration on the part of the authorities concerned. The company would be free to engage their own staff and would be responsible for them as well as for the efficiency of the fumigation itself.

The customary method of fumigation of fully loaded lighters is not readily applicable to the conditions obtaining in Colombo Harbour. If the special technique already described were adopted it might be feasible to systematically fumigate the millions of bags yearly imported from plague suspect sources in lighters, but some delay in discharge at the quayside would be inevitable and it would be difficult to provide room in the congested harbour for the specially equipped fumigating quays. Empty lighters are already subjected to a fortnightly fumigation with sulphur dioxide.

Grain can be fumigated on a very large scale without interruption of the flow of grain bags from lighter to granary in a closed mechanical conveyor fitted with revolving gas traps at each end. Reference has been made to the proposal to install such a conveyor at the top of a new three-storey elevator warehouse on the banks of the Lake-Harbour canal opposite to the granaries. Complete destruction not only of the adults fleas but of all eggs, larvæ, and pupæ, which might be immersed in the grain in the midst of the sacks would not be regularly achieved by this method with an economical length of conveyor belt, but effective pulicidal penetration to a depth of about six inches in rice bags has been shown experimentally to be possible in the workable period of half an hour using a moderate dosage of hydrogen cyanide gas. Nearly all the fully formed fleas are

found between the strands of the gunny bag or in the surface layer of rice beneath and experiments show that few would be able to penetrate sufficiently far into the bag to escape the fumes. Most of the flea eggs are adherent to gunny bags and so would be fully exposed to the gas. A fumigating conveyor of the type proposed should give a sufficient degree of grain disinfestation for plague preventive purposes.

Once installed and adjusted a conveyor fumigation plant could be operated by a small staff at small cost per bag of grain. Effective supervision would be much simpler than with any other method, and it would seem to be the only means of fumigating grain in sacks at the rate of 30,000 a day in the confined space available without delay in delivery.

The only remaining alternative method is fumigation of the stacked grain for several hours on the floor of an absolutely rat-proof sorting warehouse followed by ventilation overnight.

None of these methods of grain fumigation can be considered ideal. Under the circumstances an effective compromise between epidemiological and economic objectives must be sought.

All the methods suffer from one drawback, they involve some handling of potentially infected grain before fumigation, the danger is least in the case of fumigation in lighters and greatest when the grain is not exposed to cyanide gas before it reaches the floor of the warehouse.

The choice of fumigation method depends on economic considerations. If it is decided to mechanize the transport of all imported grain from lighter through sorting elevator to granary, then it would seem best to insert a fumigating conveyor in the circuit and pass all the grain through it.

Under existing circumstances, a thorough-going fumigation of all rice and other grains from plague infected ports is scarcely practicable. Operations must, perforce, be restricted to the really dangerous consignments.

It is proposed that all grain brought in ships showing signs of 25 or more rats from ports notifying more than 5 non-imported cases of human plague during the preceding week in the inhabited area of the port or 5 cases of rat plague in the grain mills, stores, or export premises, should be fumigated in lighters with cyanide gas before landing.

It will in any case be necessary to train a competent ship rat inspection gang in order to be in a position to grant valid certificates of exemption from deratization under Article 28 of the International Convention of 1926. In actual practice it will be found that a few ships regularly carry the great bulk of the rats. The expense and delay attending the systematic fumigation of the cargo of such ships should serve as a strong inducement to effective rat-proofing.

There are, of course, disadvantages to these somewhat arbitrary criteria of plague-suspect imports. For example, the direct transference of infected fleas in grain from Rangoon to Colombo or in cotton from Bombay is not taken into account. The risk of such fleas surviving the shorter journey from Bombay must be considerable and there can be no doubt, in view of recent findings in Madras, that cotton is a good vehicle for rat-fleas.

It is recommended in addition that raw cotton from ports plague infected as defined above should be fumigated either in lighters or in a specially constructed chamber. It is unlikely that the amount of plague-suspect cotton would exceed 1,000 bales per annum.

A further objection to the fumigation of selected consignments of grain is that it will do little to check the importation of the eggs and larvæ of dangerous plague-carrying flea, *X. cheopis*, as would a thorough fumigation of all imported grain. Some years ago this objection might have been considered fatal to any measure of partial fumigation but, unhappily, the results of recent flea surveys show that the invasion of Ceylon by *cheopis* has already progressed so far and so many local foci of *cheopis* infestation have been established in the vicinity of the grain markets of the larger towns, especially in the hill country districts, that it is too late to prevent the conquest of new zones of territory by this dangerous plague-carrying insect by measures at the ports. It has now become more important to attack the invader in its local strongholds, the granaries and markets, than to attempt to cut off fresh reinforcements from overseas.

Grain might be freed from plague-infected fleas by storage for at least seven days in absolutely rat-free warehouses, but it is very doubtful if such a proposition is economically feasible. Very prolonged storage would be required to get rid of imported foreign species of flea in the immature stages.

It would seem that rice from certain sources requires no fumigation, including that brought from South India *viâ* Dhanushkodi and Talaimannar and that imported direct to Colombo in vessels comparatively free from rats from relatively plague free ports such as Madras, Calcutta, and Coconada. Grain from Karachi may also be exempted from fumigation since it is exported in new gunny bags after exposure to sun.

The rat destruction campaign on the harbour front should be as intense as available resources permit. Each warehouse should be thoroughly trapped at least once a week, and completely cleared at least once a quarter. Barium carbonate poison baits should be laid down for fortnightly periods with intervals of about six weeks during which no baiting is done.

The protection of the Customs premises from the ingress of rats from the neighbouring plague endemic zone needs careful consideration. The mouths of all the large drains underlying this district, which occasionally discharge rats upon the harbour front should be brought below sea level. It is gratifying to learn that improvements on these lines are in active progress.

So long as the wholesale trade in grain other than rice continues to be centred in the Pettah district in premises situated over an old untrapped underground system of drains, so long will plague continue to linger in the "endemic area" and so long will there be danger of scattering the seeds of infection in grain from this source all over Ceylon. The grain stores in the Pettah endemic plague area cannot be effectively deratized when infected, nor is it possible to rat-proof them satisfactorily on their present sites. This source of plague infection could be eradicated by providing suitable new accommodation for the smaller wholesalers in the Manning Markets and compelling the larger dealers to make use of the compartments already built.

As regards the rice trade, quite a small expenditure on completing the isolation of the individual compartments of the Chalmers Granaries from one another would bring the rat population under control, limit the spread of any imported infection and make it possible to fumigate isolated compartments with cyanide gas. It would seem possible by a simple alteration in the drainage system to rat-proof the platform on which the granaries stand.

The rat-proofing of the Railway goods sheds, particularly those in all urban districts, forms the final stage of the plague preventive policy outlined. At present there is nothing to prevent a plague infected rat entraining for Kandy or any other station on the main line to the hills. The outwards goods shed lies between the two Colombo districts most liable to plague infection.

Effective rat-proofing of premises where plague-suspect goods are stored is the best permanent plague preventive measure, but it is essential that the construction should be carried out on sound lines with due regard to the habits of rats. There are certain precautions which cannot be omitted. Money spent on ill-considered attempts at rat elimination is money wasted.

The accounts of early attempts to control the spread of plague, before the fundamental facts were clearly recognized, form one of the most melancholy chapters in the history of epidemiology. The ancient belief still lingers on that plague is primarily a disease of insanitation to be combated by sanitary improvements of a general type. The truth is that there are no universally applicable plague preventive methods, the choice in any given locality must depend on an exact epidemiological study of the local conditions. The Commission for the Investigation of Plague in India, as a result of an exhaustive study of plague in relation to insanitary conditions in Bombay city, arrived at the conclusion "that the insanitary conditions in Bombay have no influence—at least none which acts directly—on the spread of epidemic plague." It is domestic rather than general hygiene which counts in the spread of human plague. If the habits of the people favour rat-infestation, the best constructed dwellings will be liable to plague. The Commission instance the severe outbreak among the inmates of some new model tenements in Bombay which left nothing to be desired in a sanitary sense but nevertheless had to be evacuated on account of excessive rat and flea infestation due entirely to the manner in which the rooms were littered with refuse and food for rats.

In Ceylon certain kinds of merchandise are the vehicles of plague rats and fleas and the foci of infection are the quarters where such goods are stored. A vast economy of effort and expense can be achieved by concentrating measures on the real danger spots and on the weak links in the chain of plague communications.

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